Chapter 30

# The Evolution and Diversity of Modern Gymnosperms and Angiosperms

## Key Topics:

- **The Evolution and Diversity of Modern Gymnosperms**
- The Evolution and Diversity of Modern Angiosperms – and development, transport and nutrition
- The Role of Coevolution in Angiosperm Diversification
- Human Influences on Angiosperm Diversification

# SEED PLANTS

## Gymnosperms and Angiosperms-
## Spermatophytes (seed-bearing plants)
## or (Lignophyte- woody plants)

# Landmarks in terrestrial plant evolution and human use

- **Evolution of seeds**
- **Reduction in the gametophyte**
- **Evolution of pollen**
- **Human utilization of seed plants**
- **Development of agriculture**

# Gymnosperms – non-flowering seed plants

- Cycads, ginkgos, gnetophytes and conifers
- Reproduce using microspores, megaspores and seeds (like angiosperms)
- Gymnosperms are seed plants
- Seeds protect and provide energy for young sporophyte
- "Naked seeds" meaning seeds are not enclosed by **fruit**

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# Angiosperms – flowering plants

- Distinguished by the presence of flowers and endosperm
- Flowers are specialized reproductive organs to enhance seed production
- Fruits develop from flowers and enclose the seed and promote seed dispersal
- Endosperm is a nutritive seed tissue

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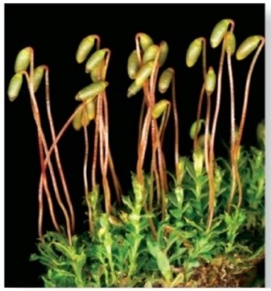
**Moss**



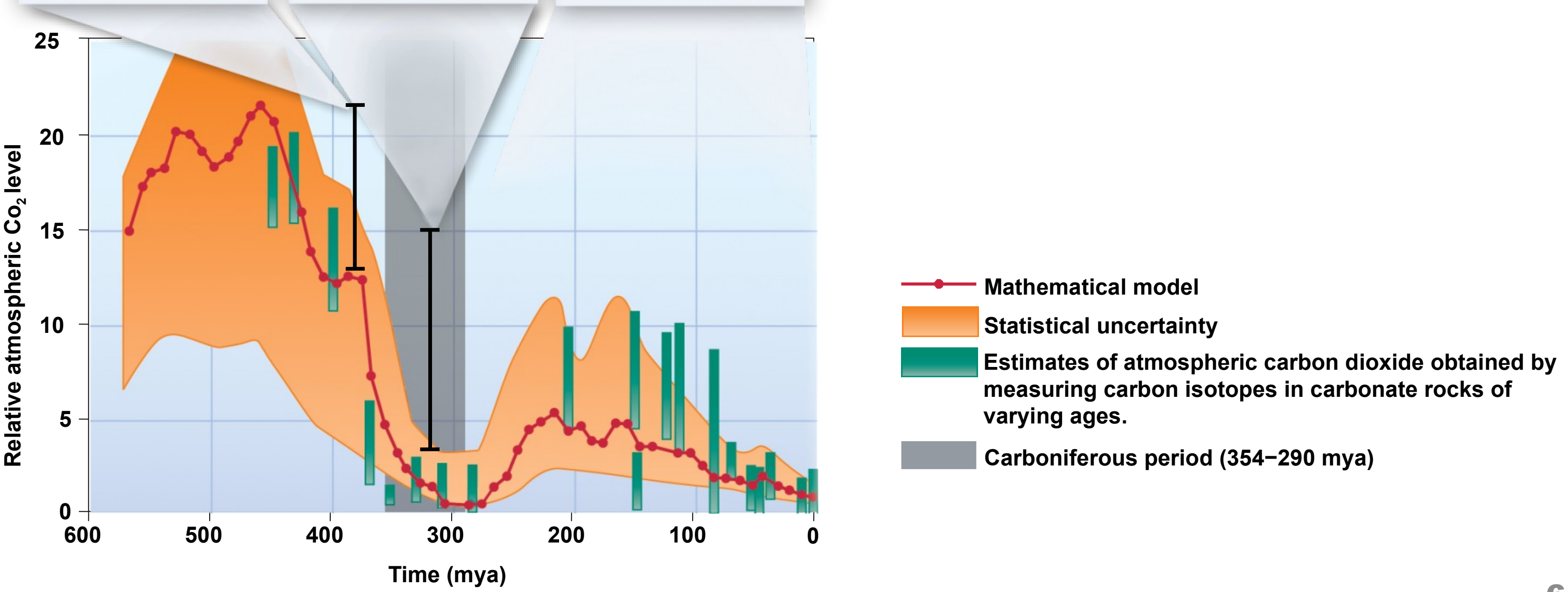
**Lycophyte**

**Conifer**

Fossil remains suggested that nonvascular land plants may have contributed to the early stages of $CO_2$ decline

The proliferation of vascular plants correlates with the most precipitous decrease in $CO_2$.

The rise and diversification of seed plants occurred after the lowest known $CO_2$ level.



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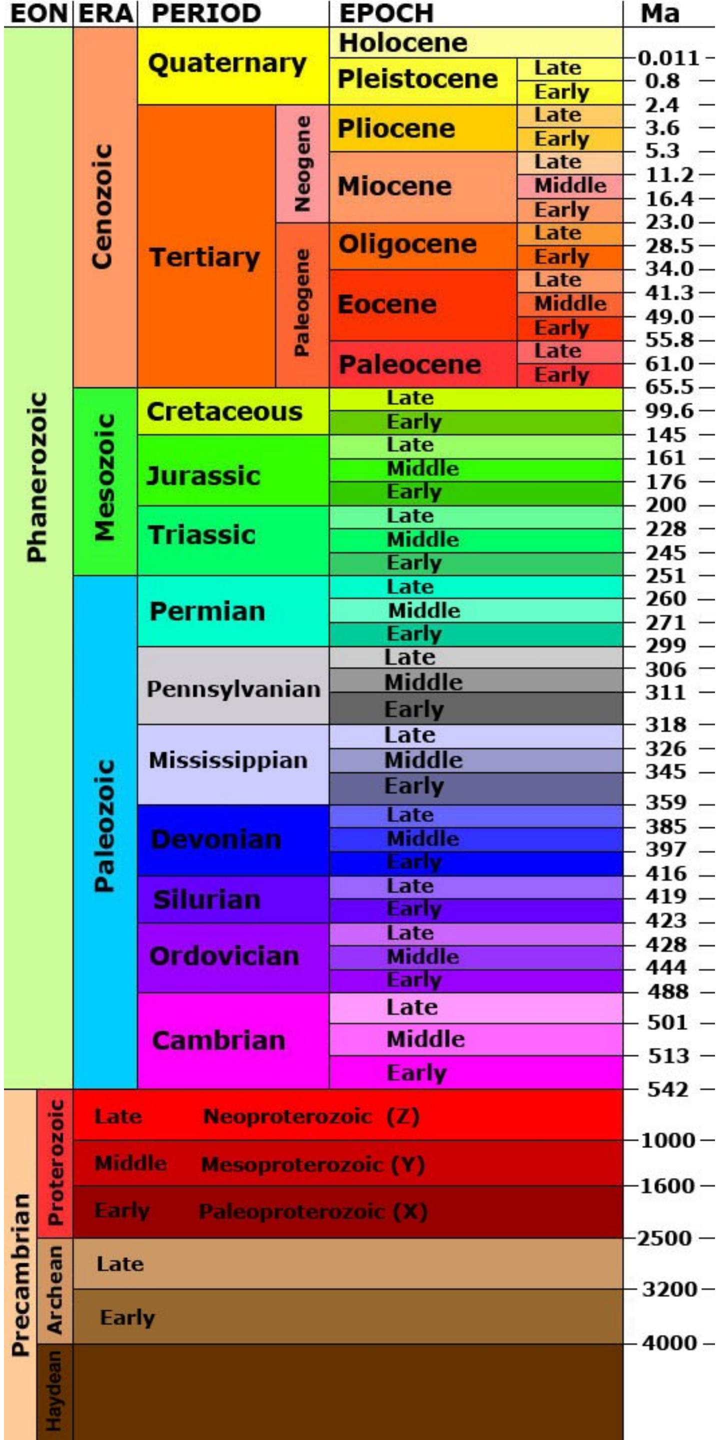
# Rise of angiosperms

- Gymnosperms and early angiosperms were probably **major sources of food** for early mammals as well as herbivorous dinosaurs
- About 65 mya, at least one large meteorite or comet crashed near the Yucatan Peninsula in Mexico…

- **K/T event** marking end of Cretaceous and beginning of Tertiary
- In the aftermath, **surviving flowering plants diversified**
- New types of animals also appeared



| EON | ERA | PERIOD | | EPOCH | | Ma |
|---|---|---|---|---|---|---|
| Phanerozoic | Cenozoic | Quaternary | | Holocene | | 0.011 |
| | | | | Pleistocene | Late | 0.8 |
| | | | | | Early | 2.4 |
| | | Tertiary | Neogene | Pliocene | Late | 3.6 |
| | | | | | Early | 5.3 |
| | | | | Miocene | Late | 11.2 |
| | | | | | Middle | 16.4 |
| | | | | | Early | 23.0 |
| | | | Paleogene | Oligocene | Late | 28.5 |
| | | | | | Early | 34.0 |
| | | | | Eocene | Late | 41.3 |
| | | | | | Middle | 49.0 |
| | | | | | Early | 55.8 |
| | | | | Paleocene | Late | 61.0 |
| | | | | | Early | 65.5 |
| | Mesozoic | Cretaceous | | Late | | 99.6 |
| | | | | Early | | 145 |
| | | Jurassic | | Late | | 161 |
| | | | | Middle | | 176 |
| | | | | Early | | 200 |
| | | Triassic | | Late | | 228 |
| | | | | Middle | | 245 |
| | | | | Early | | 251 |
| | Paleozoic | Permian | | Late | | 260 |
| | | | | Middle | | 271 |
| | | | | Early | | 299 |
| | | Pennsylvanian | | Late | | 306 |
| | | | | Middle | | 311 |
| | | | | Early | | 318 |
| | | Mississippian | | Late | | 326 |
| | | | | Middle | | 345 |
| | | | | Early | | 359 |
| | | Devonian | | Late | | 385 |
| | | | | Middle | | 397 |
| | | | | Early | | 416 |
| | | Silurian | | Late | | 419 |
| | | | | Early | | 423 |
| | | Ordovician | | Late | | 428 |
| | | | | Middle | | 444 |
| | | | | Early | | 488 |
| | | Cambrian | | Late | | 501 |
| | | | | Middle | | 513 |
| | | | | Early | | 542 |
| Precambrian | Proterozoic | Late | | Neoproterozoic (Z) | | 1000 |
| | | Middle | | Mesoproterozoic (Y) | | 1600 |
| | | Early | | Paleoproterozoic (X) | | 2500 |
| | Archean | Late | | | | 3200 |
| | | Early | | | | 4000 |
| | Haydean | | | | | |

# Critical innovations in plant evolution

- New features that fostered the diversification of plant phyla:
  - ❑**Embryos**
  - ❑**Leaves**
  - ❑**Seeds**

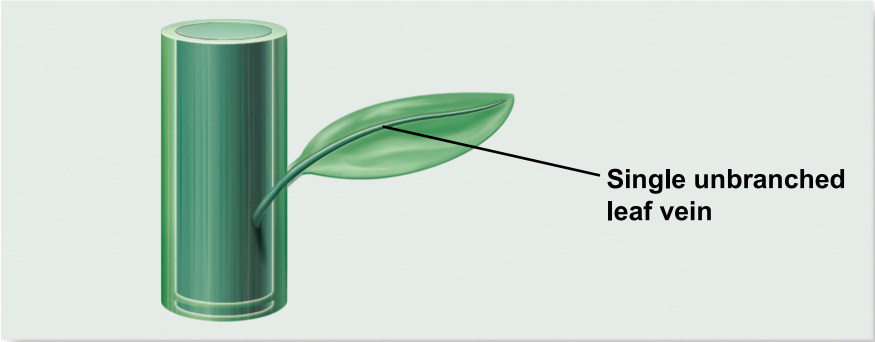
# The Origin and Evolutionary Importance of the Plant Embryo

- One of the first critical innovations of land plants
- Plant embryos are **young sporophytes** that develop from zygotes (fertilized eggs)
- Three features
    - Multicellular and diploid
    - Zygotes and embryos retained in maternal tissue
    - Depends on organic and mineral materials supplied by mother plant – placental transfer tissues

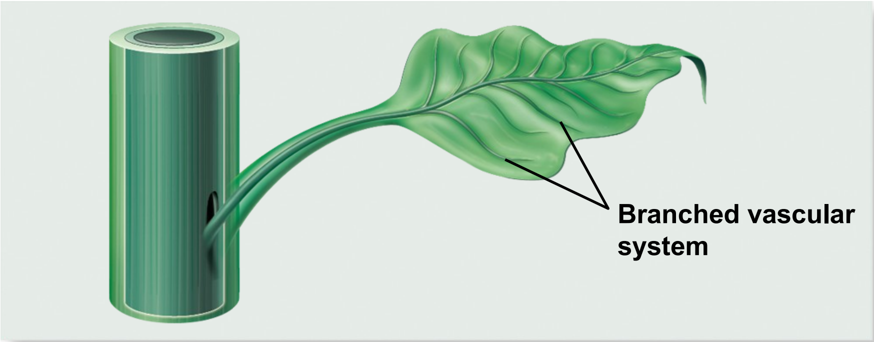
# The Origin and Evolutionary Importance of Leaves and Seeds

- Leaves provide a **large surface area** that helps leaves to effectively capture sunlight for use in photosynthesis
- Lycophytes produce the simplest, most ancient leaves called **lycophylls** or **microphylls**

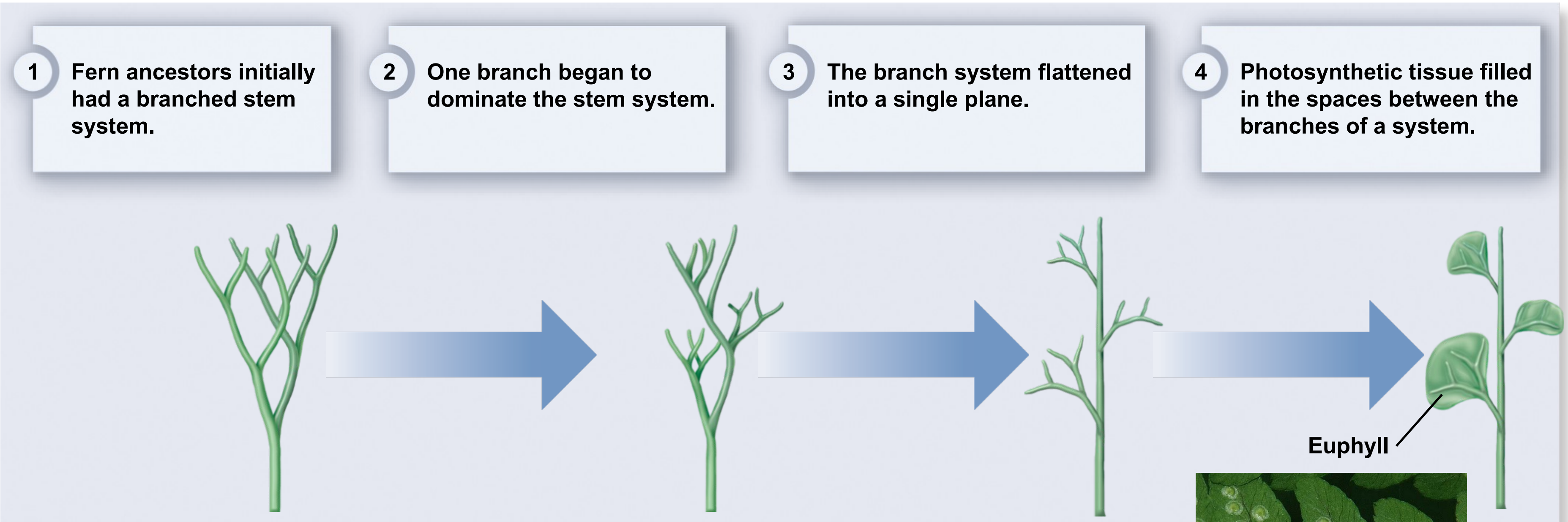
- Other vascular plants have leaves with extensively branched veins – **euphylls** or **megaphylls**
  - ❑ Larger size provides considerable selective advantage
  - ❑ Evolved in a series of steps



(a) Lycophyll (small leaf)



(b) Euphyll (large leaf)



1 Fern ancestors initially had a branched stem system.

2 One branch began to dominate the stem system.

3 The branch system flattened into a single plane.

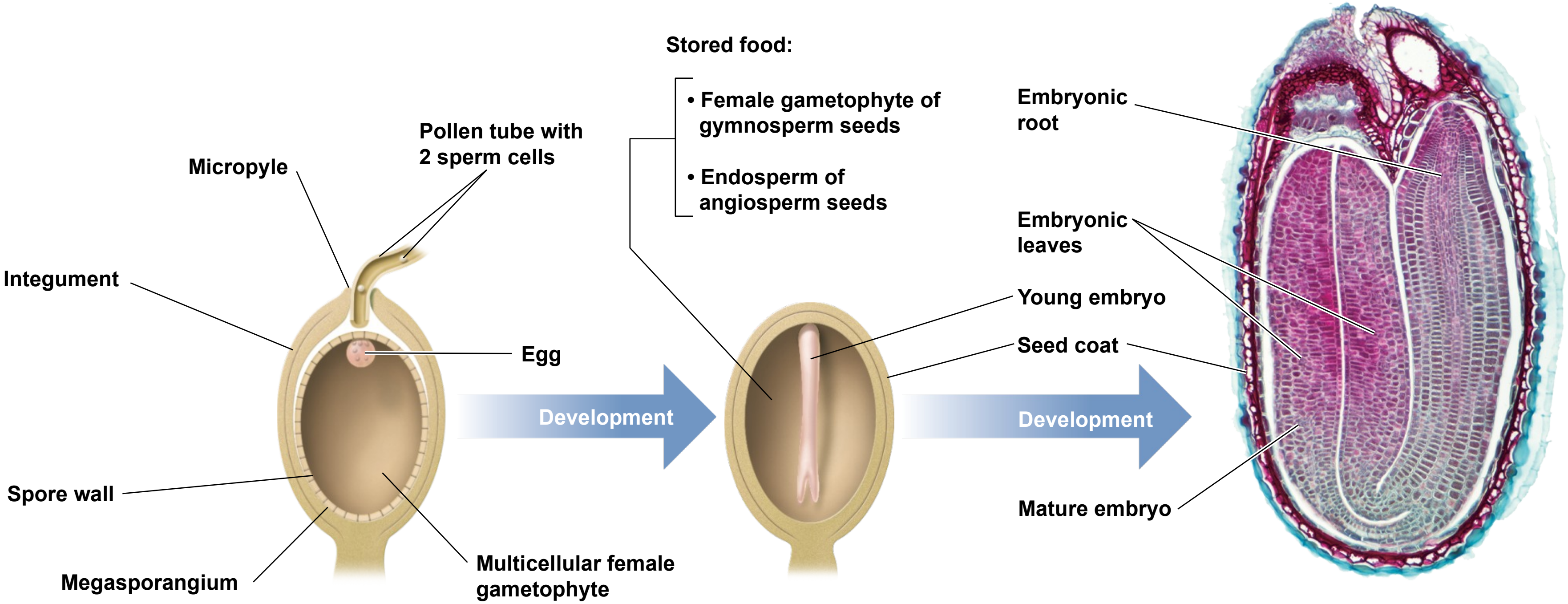
4 Photosynthetic tissue filled in the spaces between the branches of a system.

(c) Euphyll evolution process in pteridophytes

# Origin of seeds

- **Ovule**
  - Sporangium with single spore and a very small egg-producing gametophyte inside
  - Enclosed by integuments (coverings)
- **Seed plants** produce two distinct types of spores in two different types of sporangia
  - Microspores in microsporangia – male gametophytes = **pollen**
  - Megaspores in megasporangia – female gametophyte = **eggs**

# General seed development



(a) Mature ovule just prior to fertilization

(b) Developing seed

(c) LM of mature angiosperm seed, sectioned and stained

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# Ecological advantages of seeds

- Seeds are considered to be a key adaptation to reproduction in a **terrestrial** habitat
- Able to remain **dormant** in the soil – can wait for favorable conditions
- Adaptations to **improve dispersal**
- Can store considerable amounts of **food**
- Sperm can reach egg **without having to swim through water**

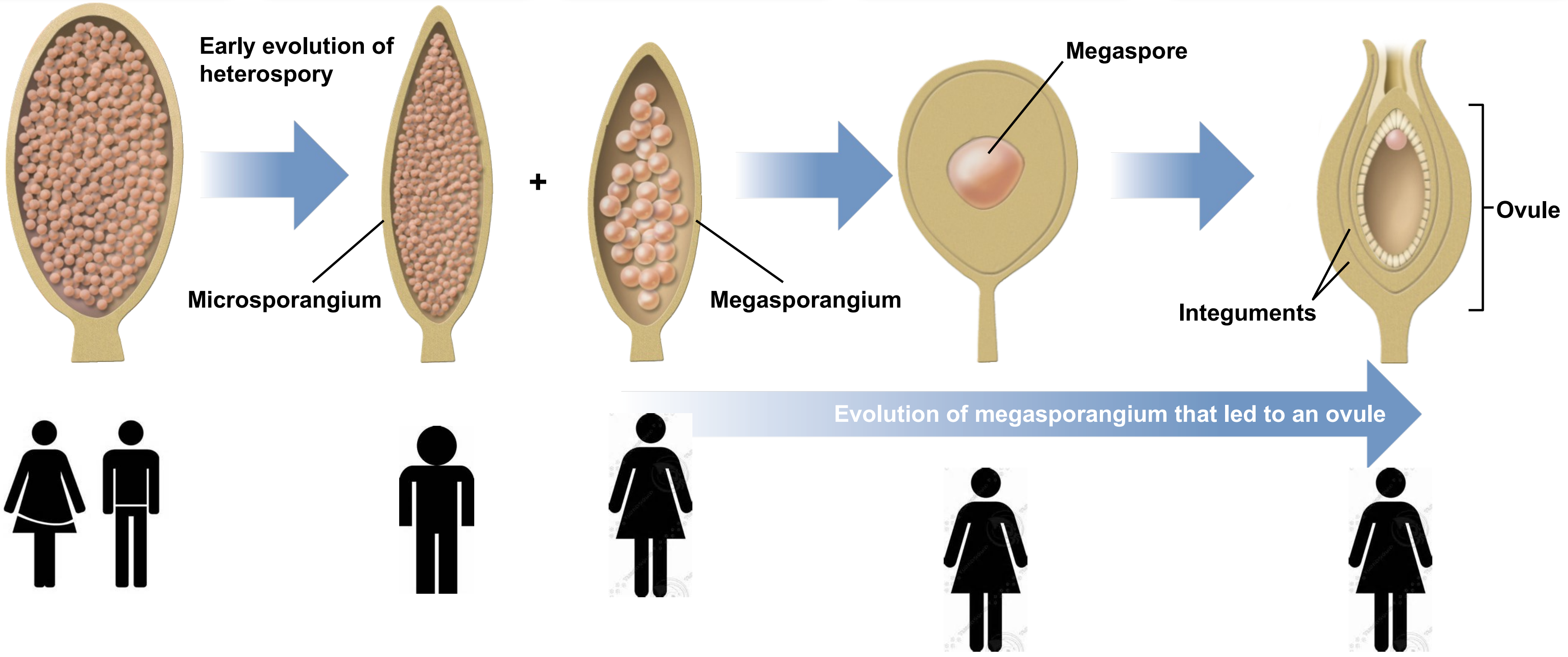
1 **Sporangium containing spores that are similar in size**

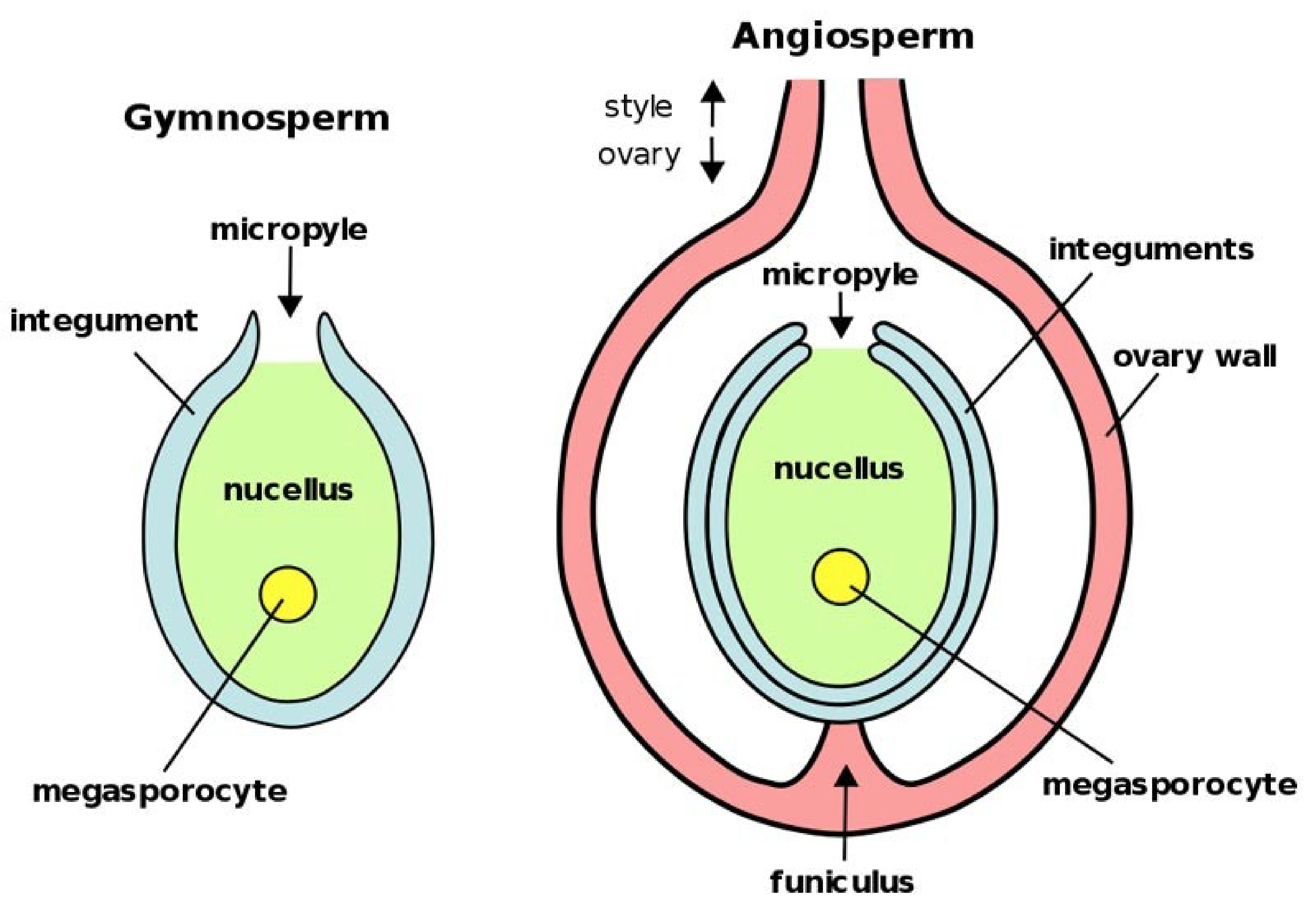
2a **Microsporangium containing many small microspores**

2b **Megasporangium containing fewer, larger megaspores**

3 **Reduction to 1 megaspore per megasporangium**

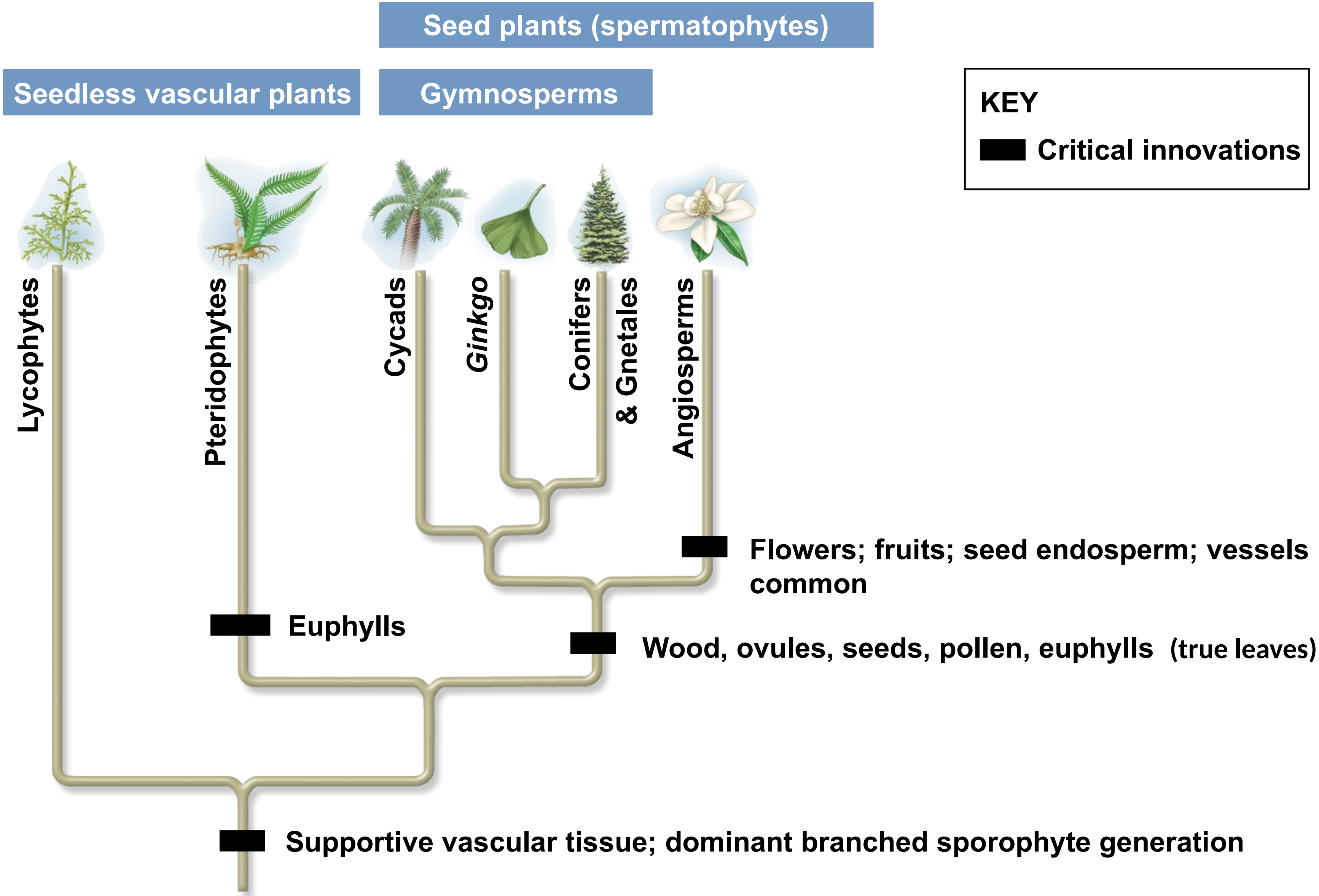
4 **Enclosure of megasporangium within integuments to form ovule; when fertilized,ovule develops into a seed**


Early evolution of heterospory
Microsporangium
+
Megasporangium
Megaspore
Integuments
Ovule
Evolution of megasporangium that led to an ovule


Gymnosperm
micropyle
integument
nucellus
megasporocyte
Angiosperm
style
ovary
micropyle
integuments
ovary wall
nucellus
megasporocyte
funiculus

# Overview of the seed plants

- First seed plants (spermatophytes) evolved from earlier seedless vascular plants similar to modern lycophytes (club moss) and pteridophytes (fern)
- Following the early diversification of gymnosperms, one ancestral gymnosperm lineage gave rise to the angiosperms, the flowering plants



**Seed plants (spermatophytes)**

**Seedless vascular plants**

**Gymnosperms**

**KEY**

■ **Critical innovations**

**Lycophytes**

**Pteridophytes**

**Cycads**

***Ginkgo***

**Conifers**

**& Gnetales**

**Angiosperms**

■ **Flowers; fruits; seed endosperm; vessels common**

■ **Euphylls**

■ **Wood, ovules, seeds, pollen, euphylls** (true leaves)

■ **Supportive vascular tissue; dominant branched sporophyte generation**

# Major critical innovations

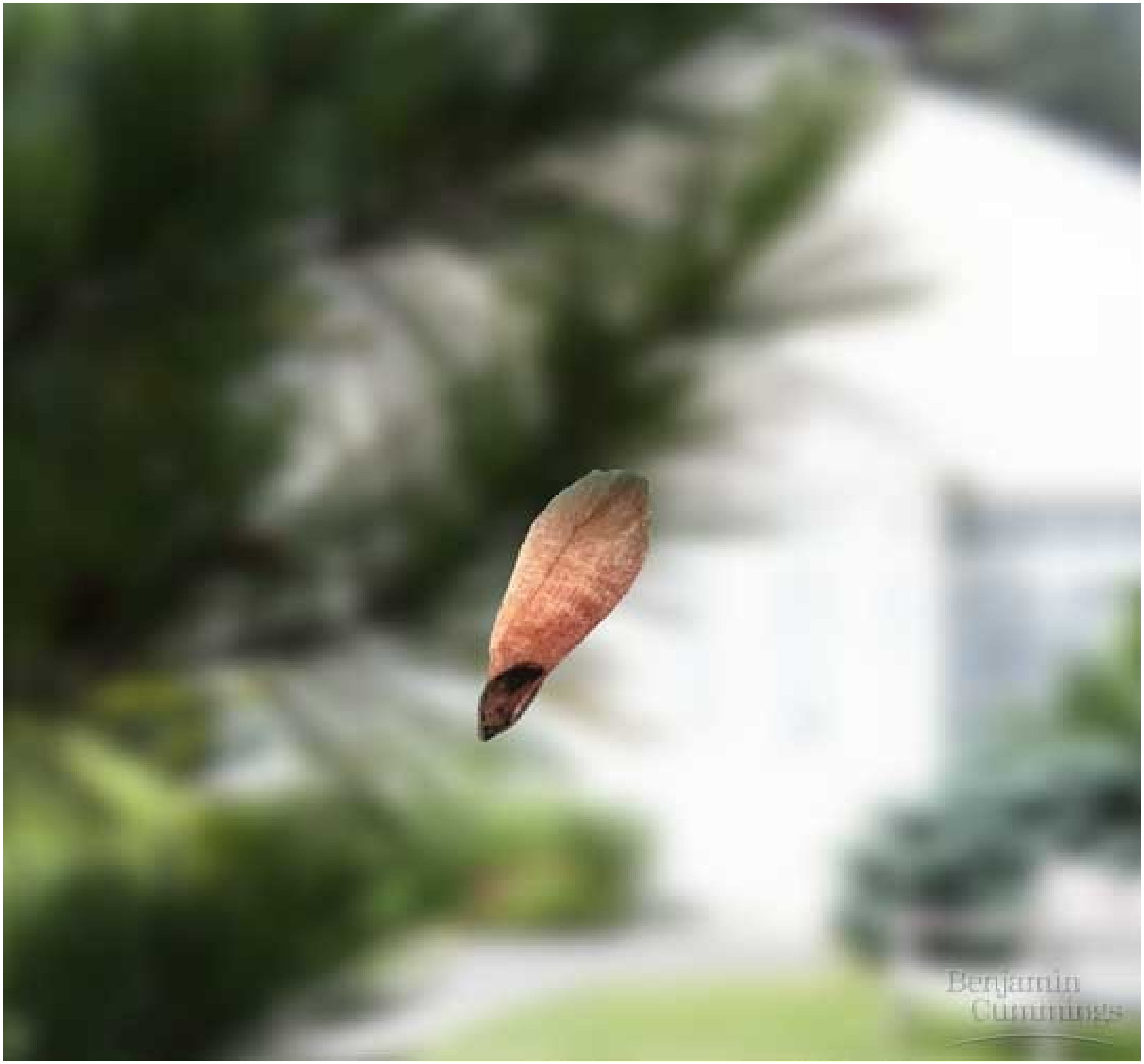
- ❑Shared by **all** seed plants:
  - ❑**Pollen** allows seed plants to disperse male gametophytes
  - ❑**Ovules** provide protection and nutrition to female gametophytes and embryos
  - ❑**Seeds** allow plants to reproduce in diverse habitats
- ❑And shared by some:
  - – **Wood** strengthens plants, allowing them to grow tall and produce many branches, leaves, and seeds

# The Evolution and Diversity of Modern Gymnosperms

- Produce seeds that are exposed rather than enclosed in ovary or fruit
- **“Naked seeds”**
- **Most modern forms are woody shrubs or trees**
- Seeds and wood were adaptations that allowed gymnosperms to cope with global climate changes and to live in relatively cold and dry habitats

# Fossilized Seed

# Winged seed of a White Pine (*Pinus strobus*)

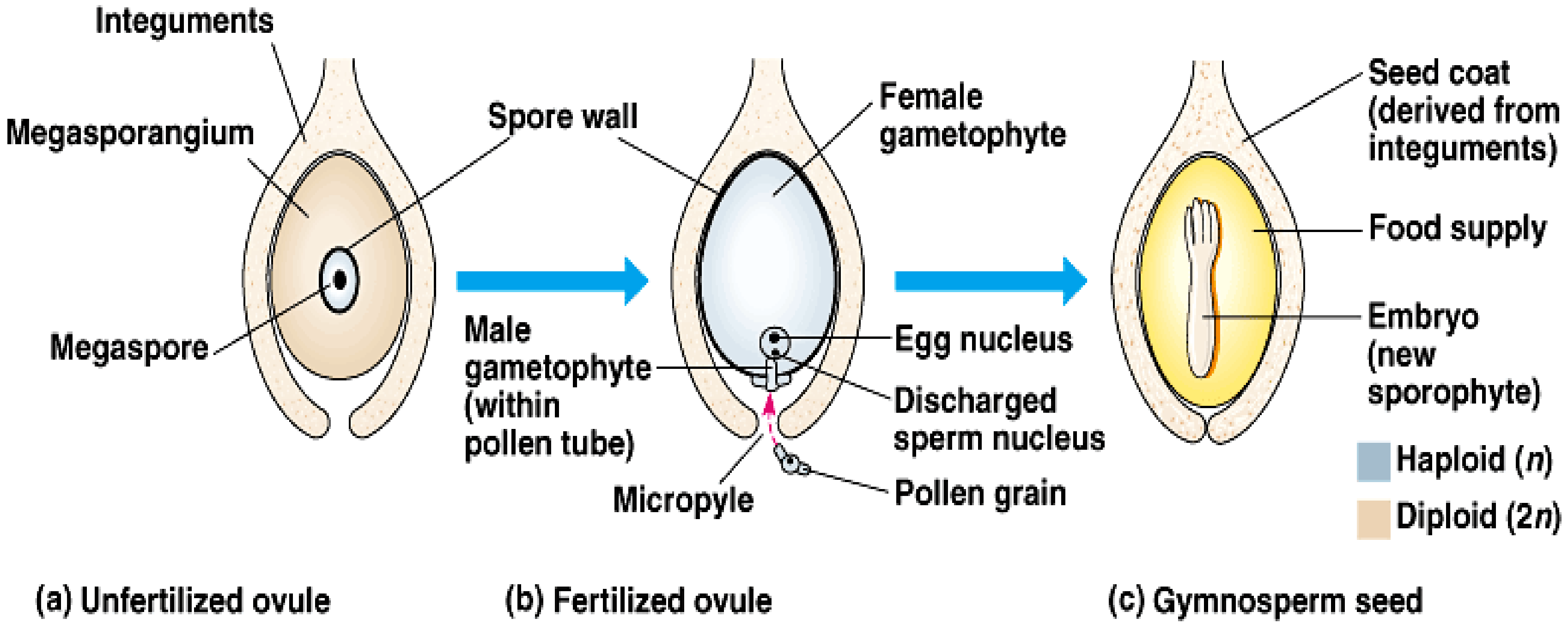


# GYMNOSPERMS

GNETOPHYTA
GINKGOPHYTA
CYCADOPHYTA
CONIFEROPHYTA

# From ovule to seed

## Gymnosperm



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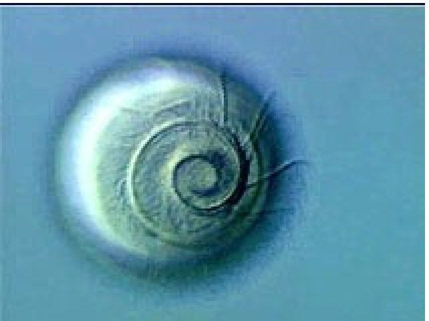
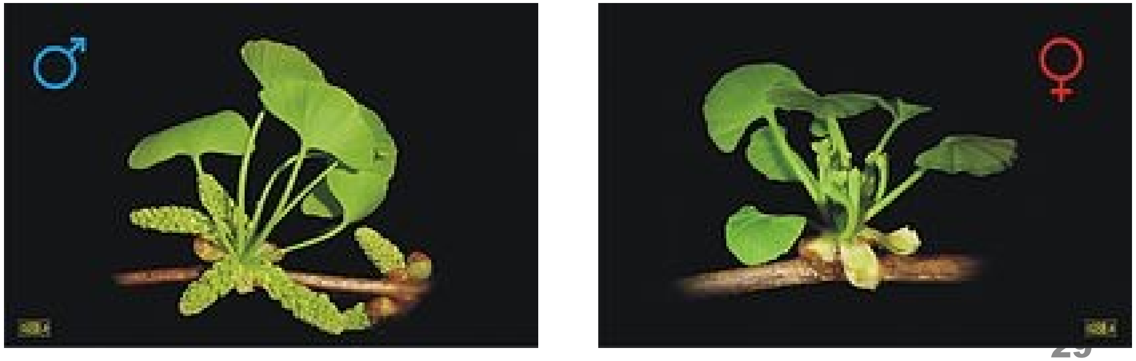
# CHARACTERISTICS OF GYMNOSPERMS

- Sporophyte dominant: Gametophyte very reduced
- On the sporophyll (female cone scale): An ovule (modified megasporangium (2n)), after meiosis, produces a megaspore (n), which divides to become the multicellular female gametophyte with archegonium + egg
- On the sporophyll (male cone scale): The microsporangia (2n), after meiosis, produces microspores (n), which divide to become 2-celled male gametophyte (pollen grain) with 2 sperm nuclei
- after fertilization and formation of zygote, the embryo becomes a seed.
- no external water required for fertilization
- vascular cambium leads to secondary growth (wood)
- **“NAKED” SEEDS DEVELOP ON SPOROPHYLLS**

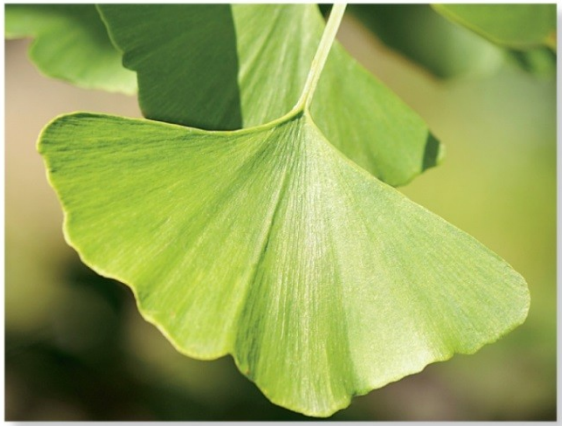
# Phylum Ginkgophyta

- *Ginkgo biloba* is single remaining living species
- Nearly extinct in the wild
- Widely planted along city streets (only males – hopefully)
- Individual trees produce either ovules and seeds or pollen
- Flagellated sperm

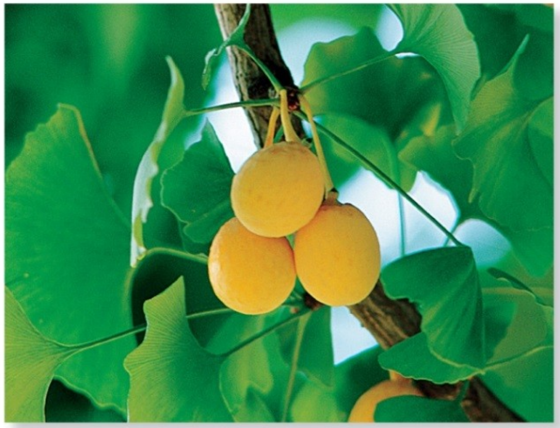




(a) ***Ginkgo biloba*** **tree**



(b) ***Ginkgo biloba*** **leaf**

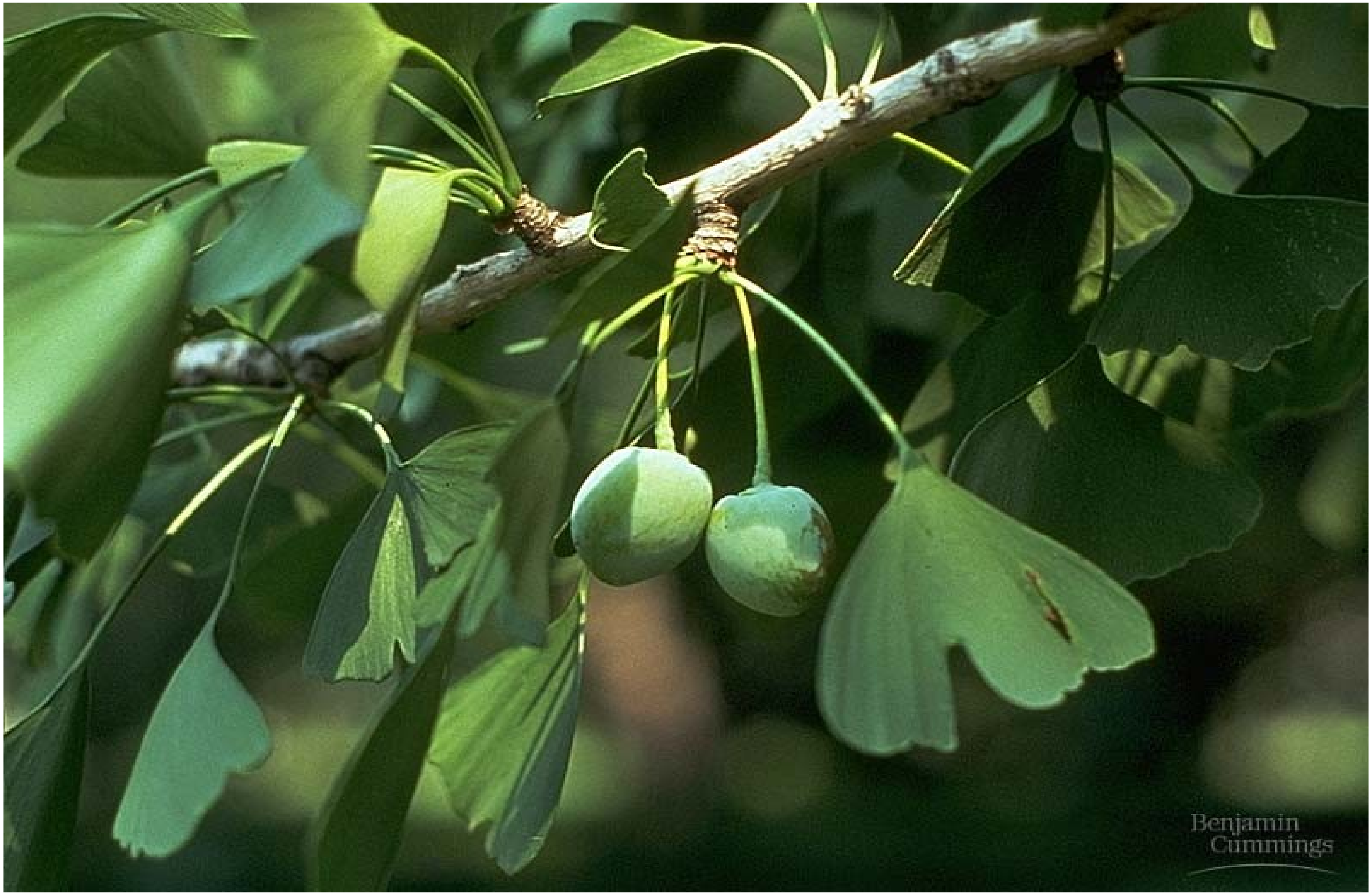


(c) ***Ginkgo biloba*** **seeds**

a: © Karlene V. Schwartz; b: © Fancy Photography/Veer RF; c: © TOPIC PHOTO AGENCY IN/agefotostock

- Ginkgos are long-lived trees – individuals can live for **more than a thousand years** and grow to **30 m** in height

# Phylum Ginkgophyta: *Ginkgo biloba* (seeds)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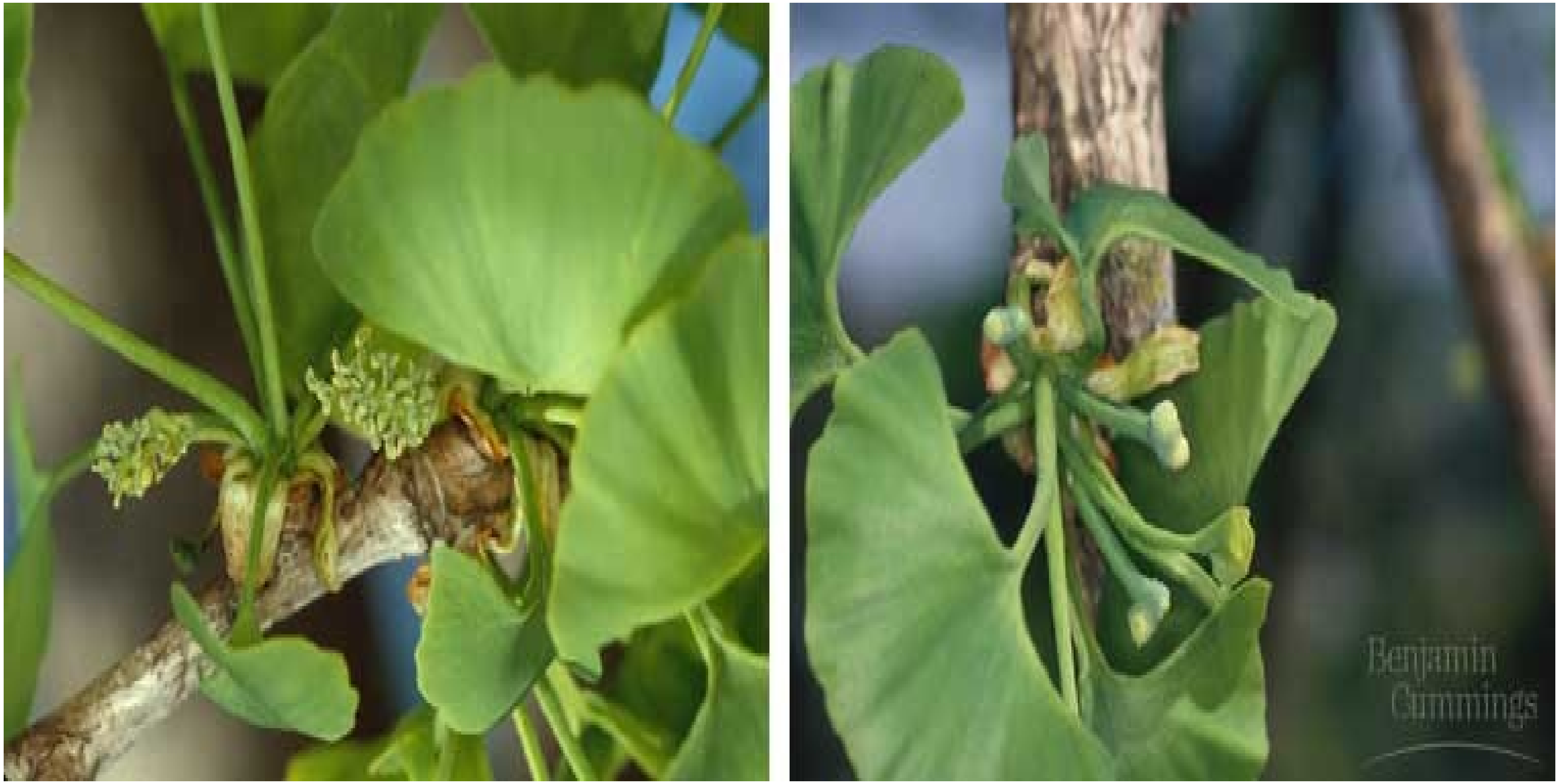
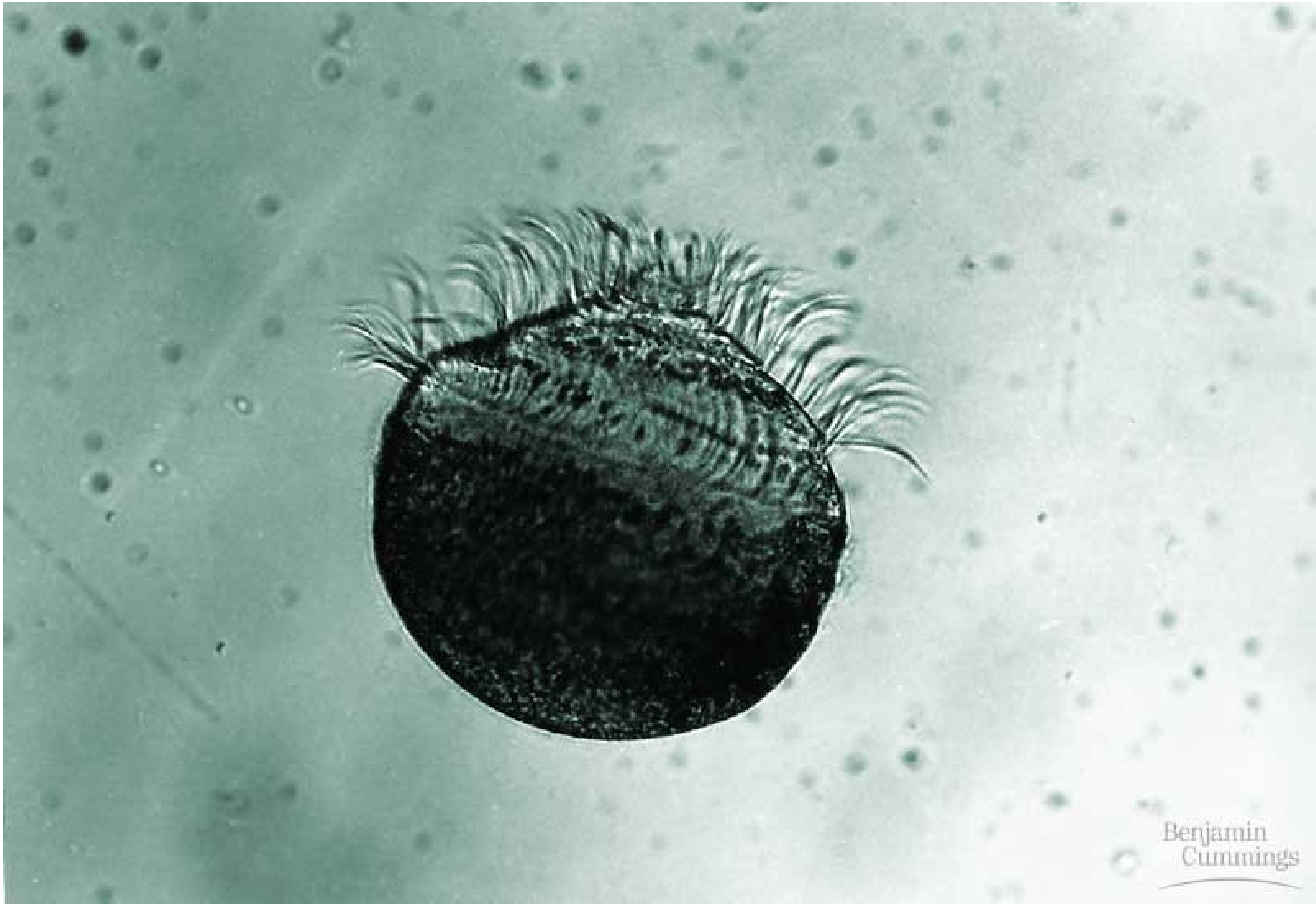
# Ginkgo: Male (left), female (right)



# Ginkgo sperm – flagellated (similar to Charophyaceans)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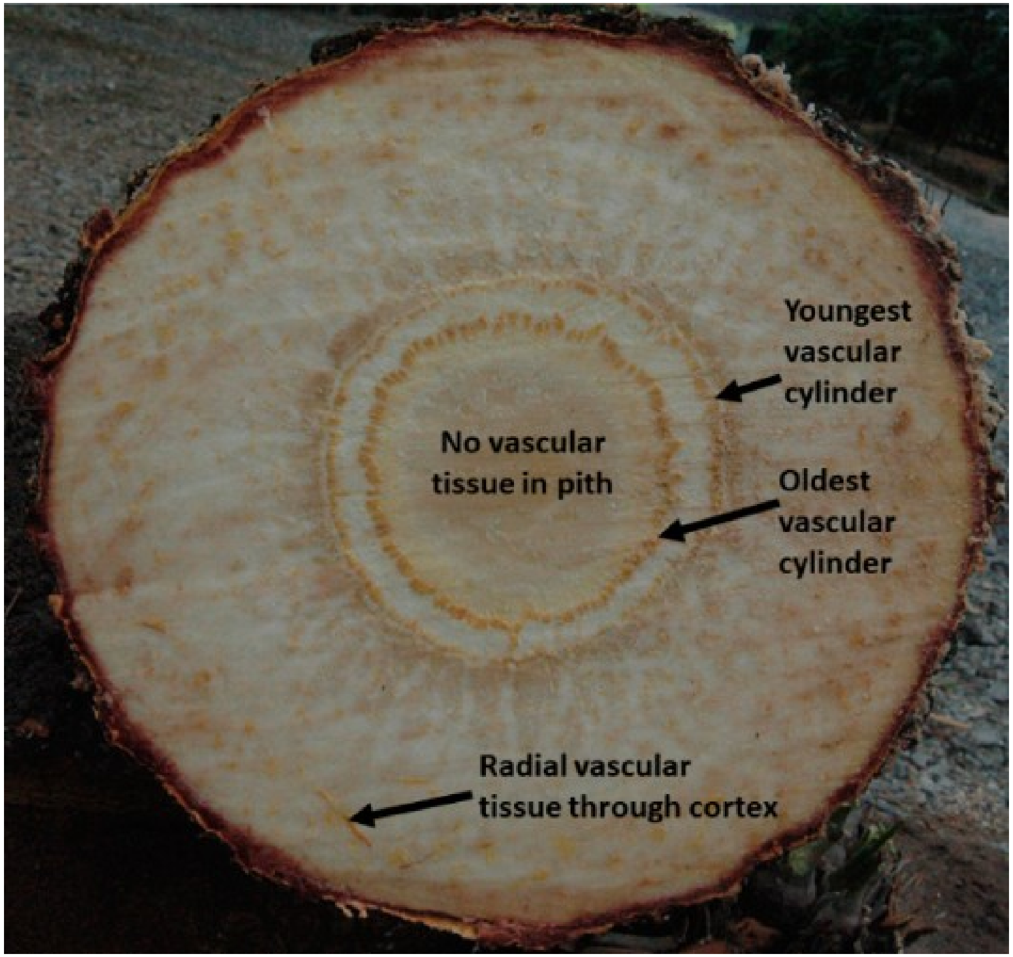
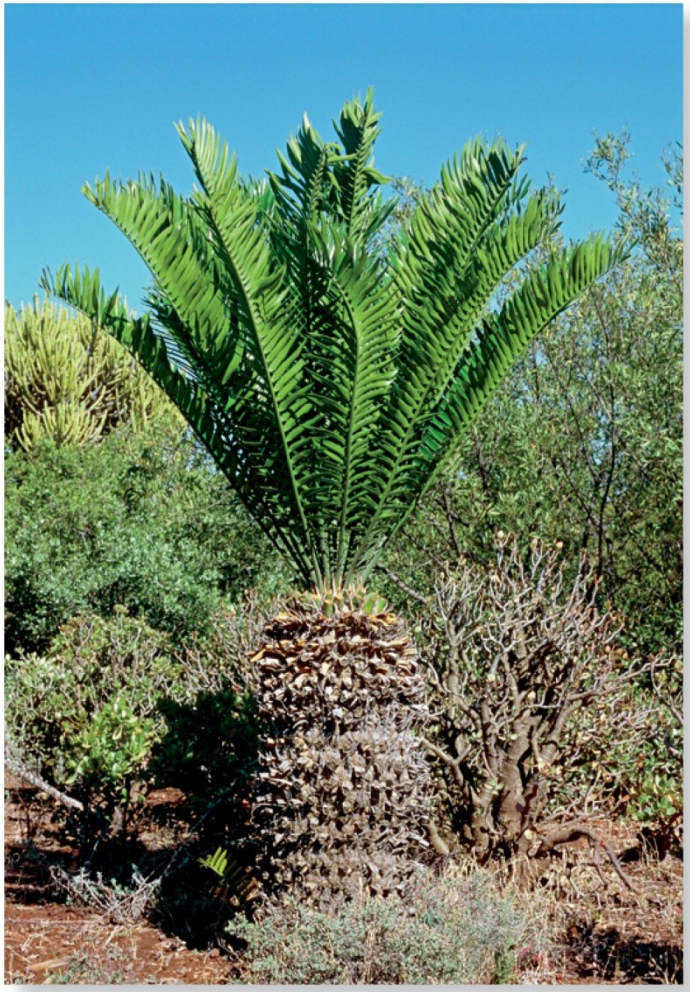
# Phylum Cycadophyta

- 300 cycad species today
- Primarily tropical and subtropical
- Many species are rare, with habitats threatened by human activities
- Non-woody stems (mostly pith, no growth rings) may emerge like tree trunks or be underground
- Leaves palm-like e.g. Sago “palm”

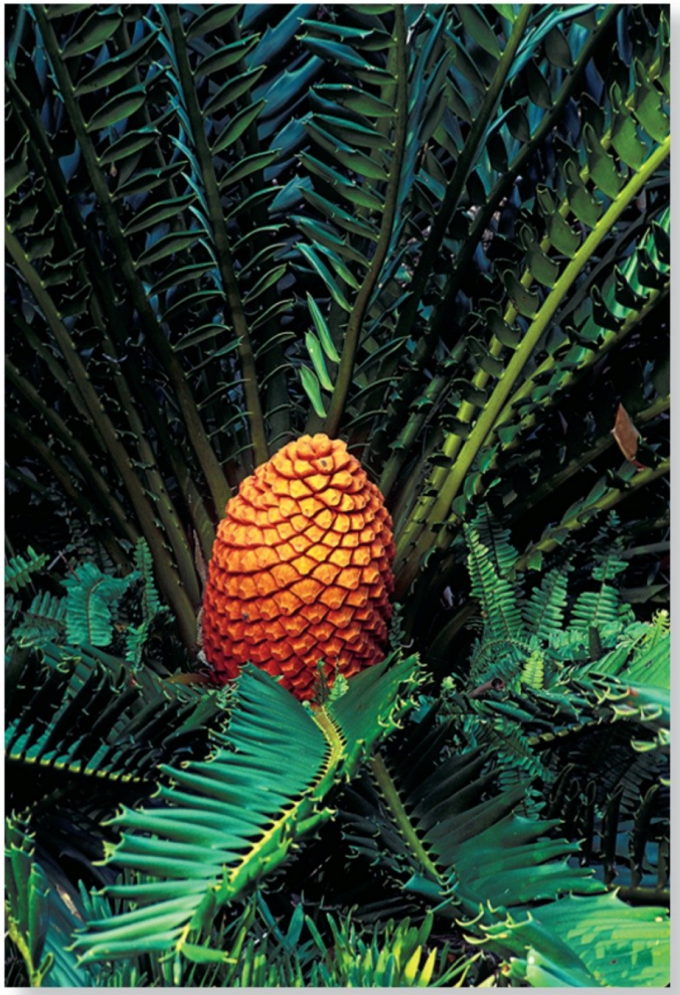
# Cycad stem cross section


Youngest vascular cylinder
No vascular tissue in pith
Oldest vascular cylinder
Radial vascular tissue through cortex

https://www.mdpi.com/2223-7747/7/4/94/htm



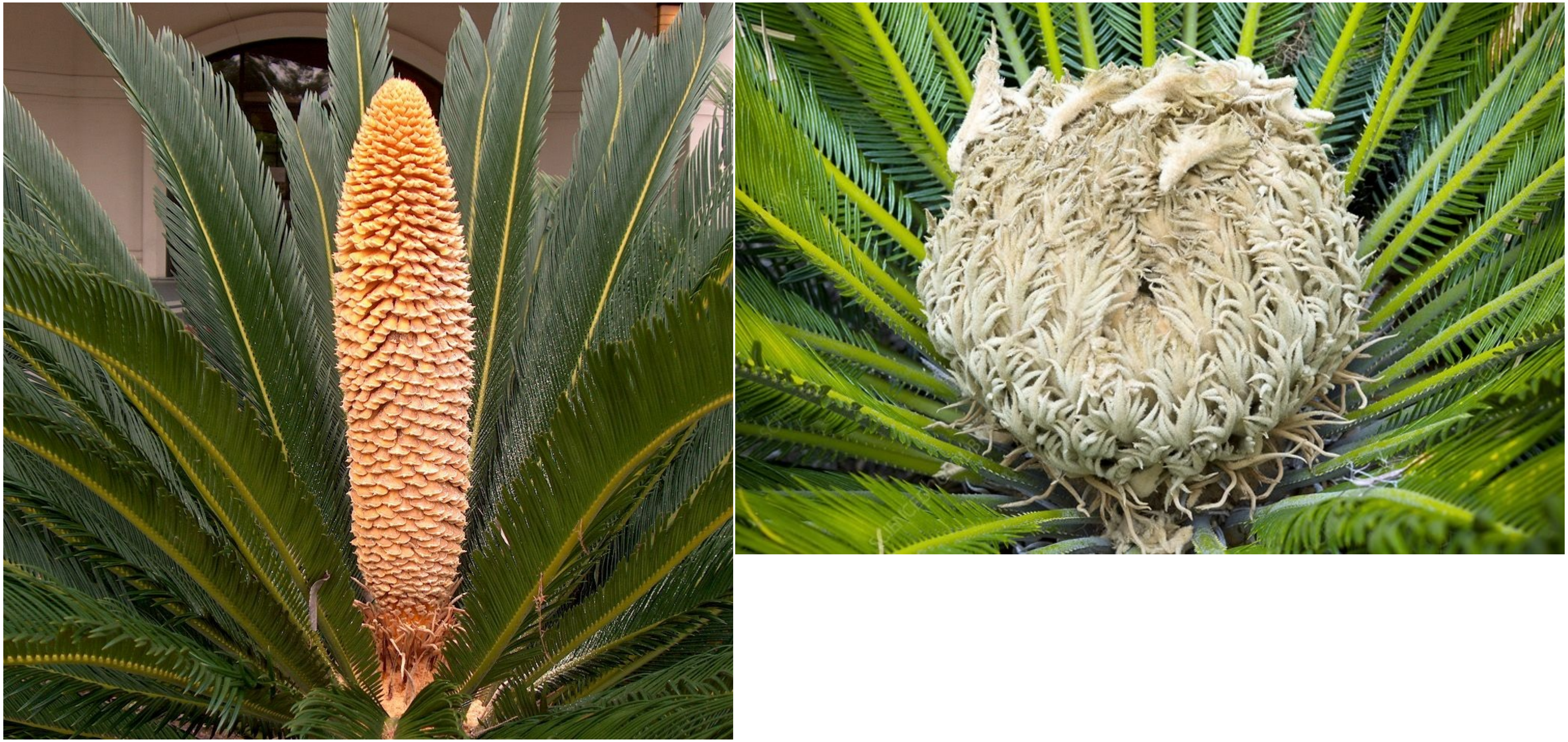
**(a) Emergent cycad stem**



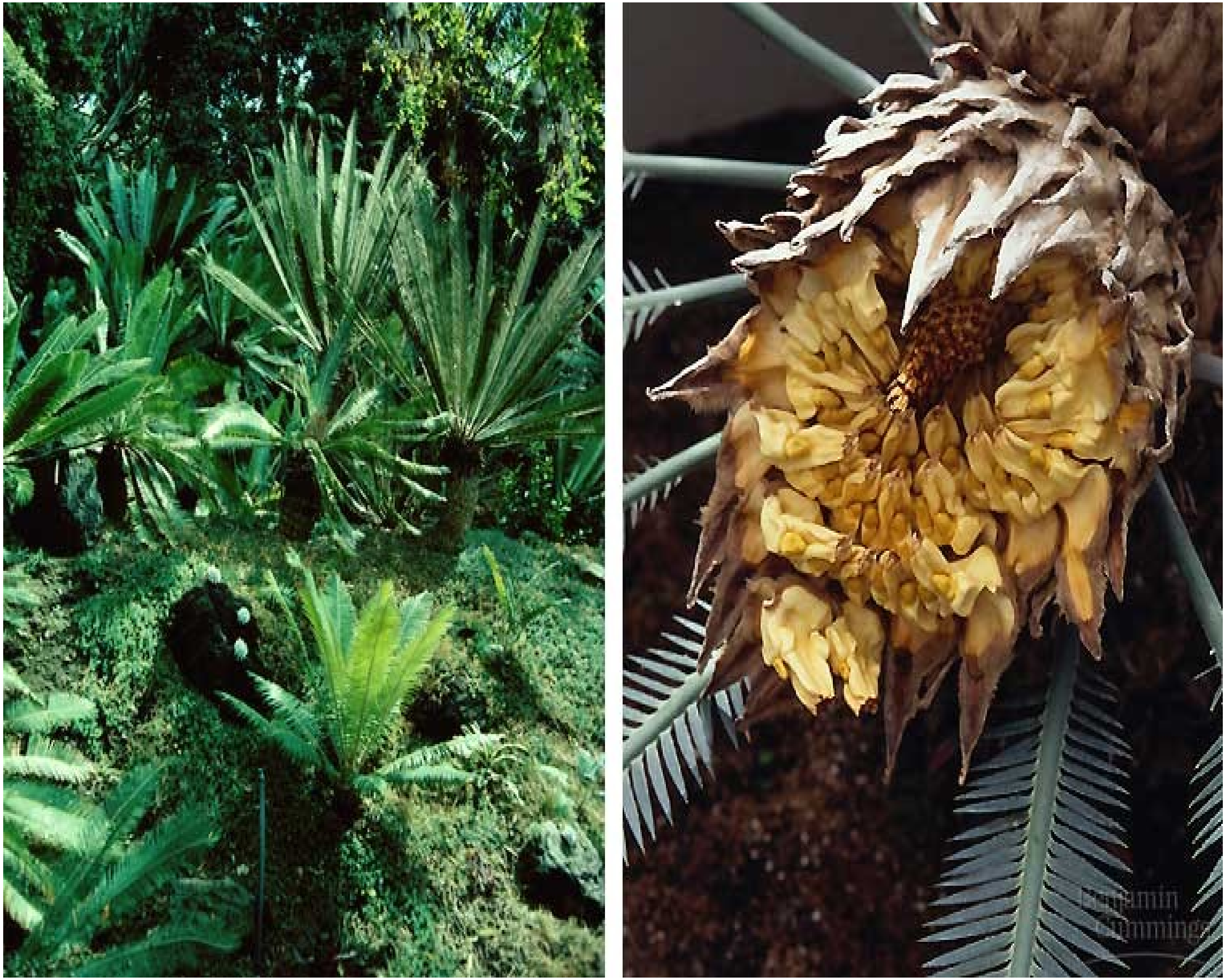
**(b) Submergent cycad stem**

a: © Philippe Psaila/Photo Researchers, Inc.; b: © Ed Reschke/Getty Images

# Male and female cycad cone



# Phylum Cycadophyta: cycads



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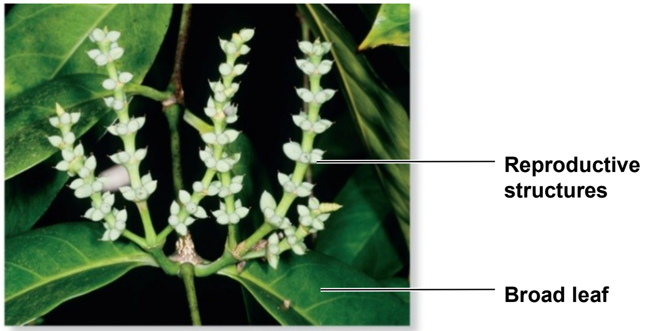
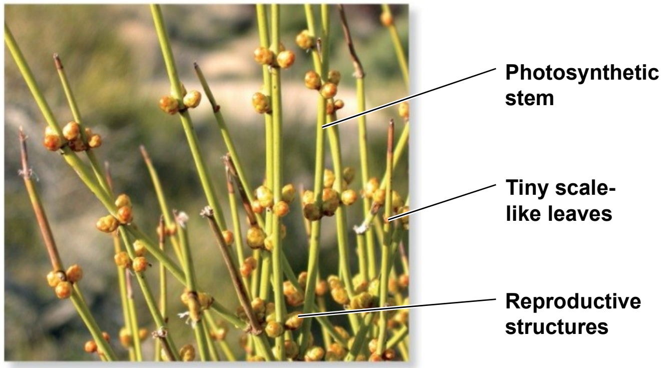
# Phylum Gnetophyta

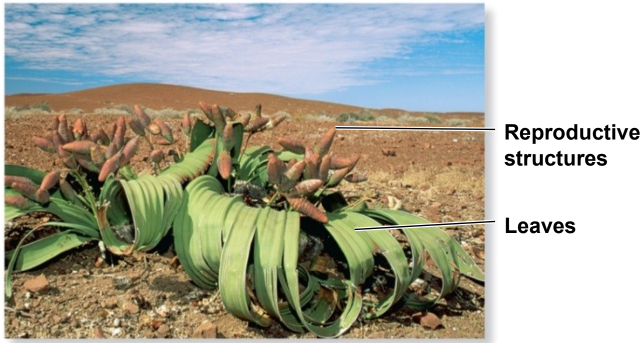
- Genus ***Gnetum***
  - Has broad leaves similar to tropical plants
  - Vines, shrubs or trees in tropical Africa or Asia
- Genus ***Ephedra***
  - Native to arid SW US
  - Ephedrine - banned
- Genus ***Welwitschia***
  - 1 living species
  - Coastal Namib Desert in SW Africa
  - Long taproot and 2 very long leaves
  - Obtains water from coastal fog
  - May live to 1000 yrs



**(a) Genus *Gnetum***



**(b) *Ephedra californica***



**(c) *Welwitschia mirabilis***

a: © Robert & Linda Mitchell; b: © 2004 James M. Andre; c: © Michael & Patricia Fogden/Corbis

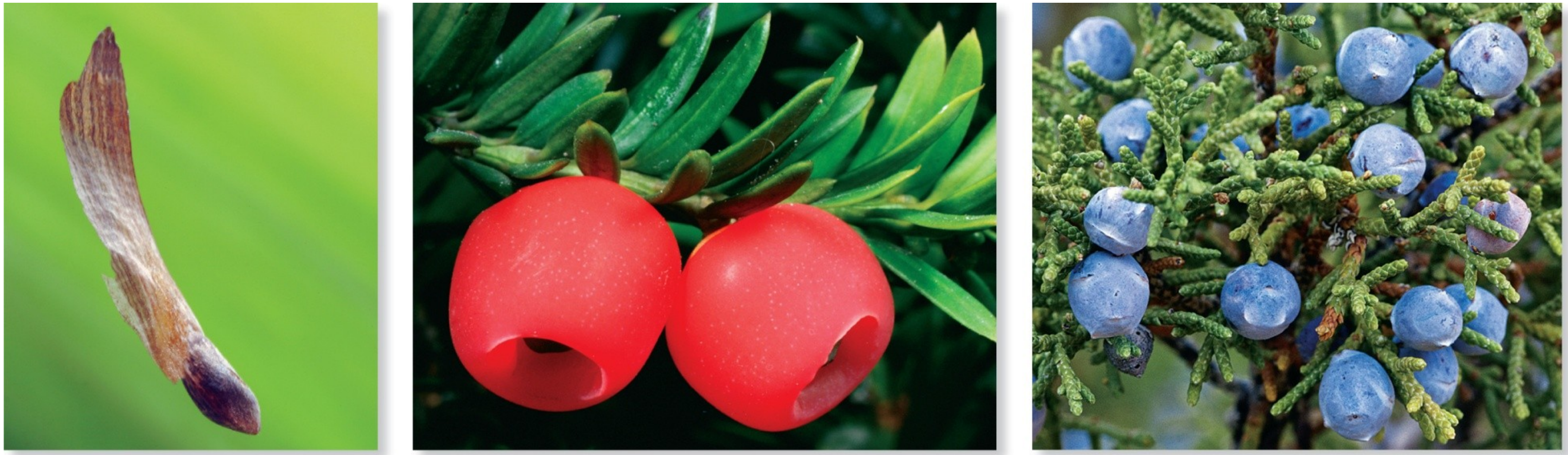
# PHYLUM CONIFEROPHYTA

- Named for seed cones
- 500 species in 50 genera
- Particularly common in mountain and high-latitude forests
- Vitally important to humans

- Simple pollen cones
    - Scale-like structures bearing microsporangia with pollen

- More complex ovule-bearing cones
    - Composed of short branch system that bears ovules

- Mature pollen wind dispersed

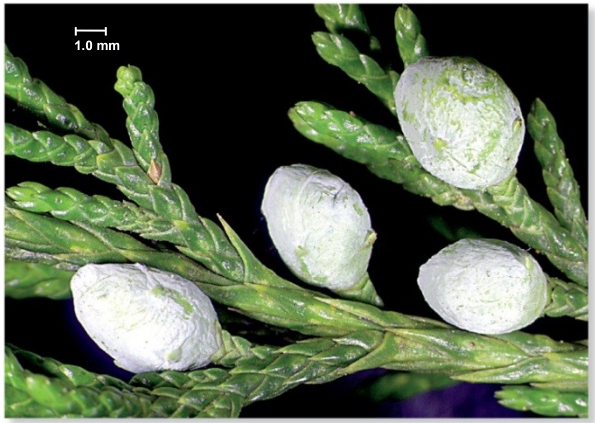


**(a) Pine seed** **(b) Yew seeds** **(c) Juniper cones with seeds**

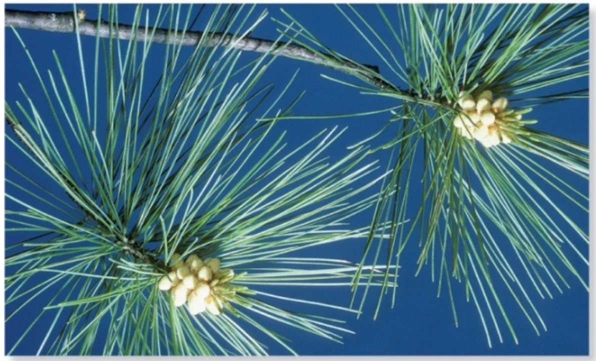
a: © Zach Holmes Photography; b: © Duncan McEwan/naturepl.com; c: © Ed Reschke/Getty Images

- Some seed coats have wings for wind dispersal
- Others produce seeds or cones with brightly colored, fleshy coatings to attract birds for dispersal

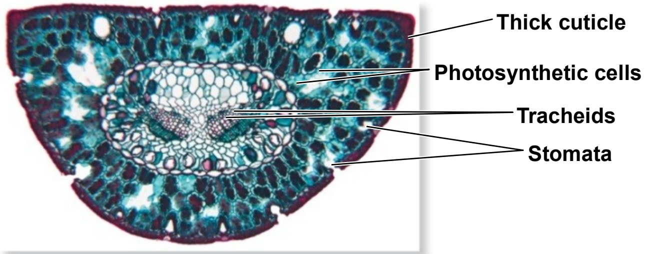
- **Cold climate adaptations**
  - Conical shape and flexible branches
  - Scale-like or needle-shaped leaves
  - Thick waxy cuticle
- Most conifers are **evergreens**



(a) Scale-shaped leaves of Eastern red cedar

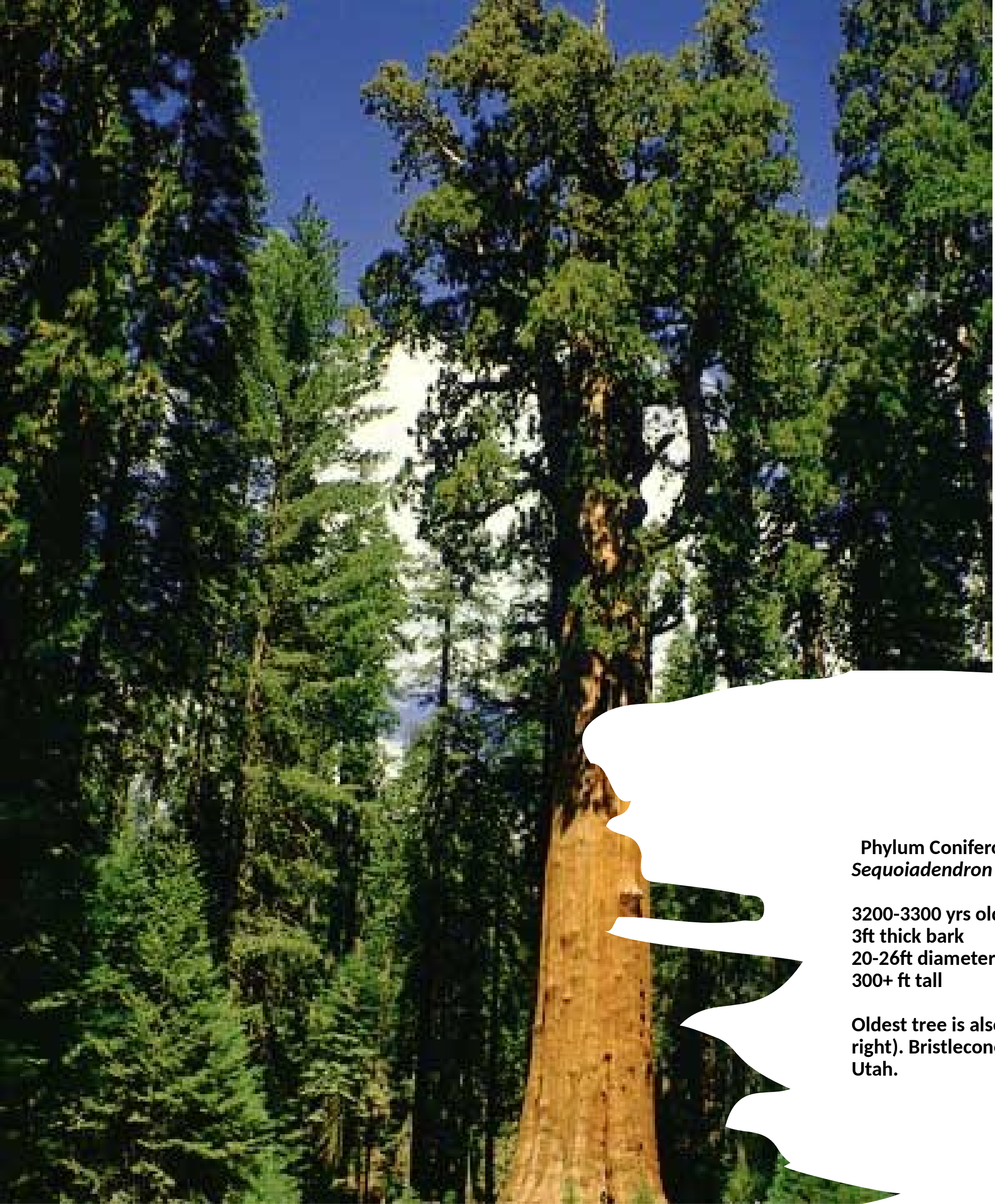


(b) Needle-shaped leaves of pine



(c) Stained cross section of pine needle, showing the thick cuticle

a: © Steven P. Lynch; b: © Ken Wagner/Phototake; c: © Lee W. Wilcox

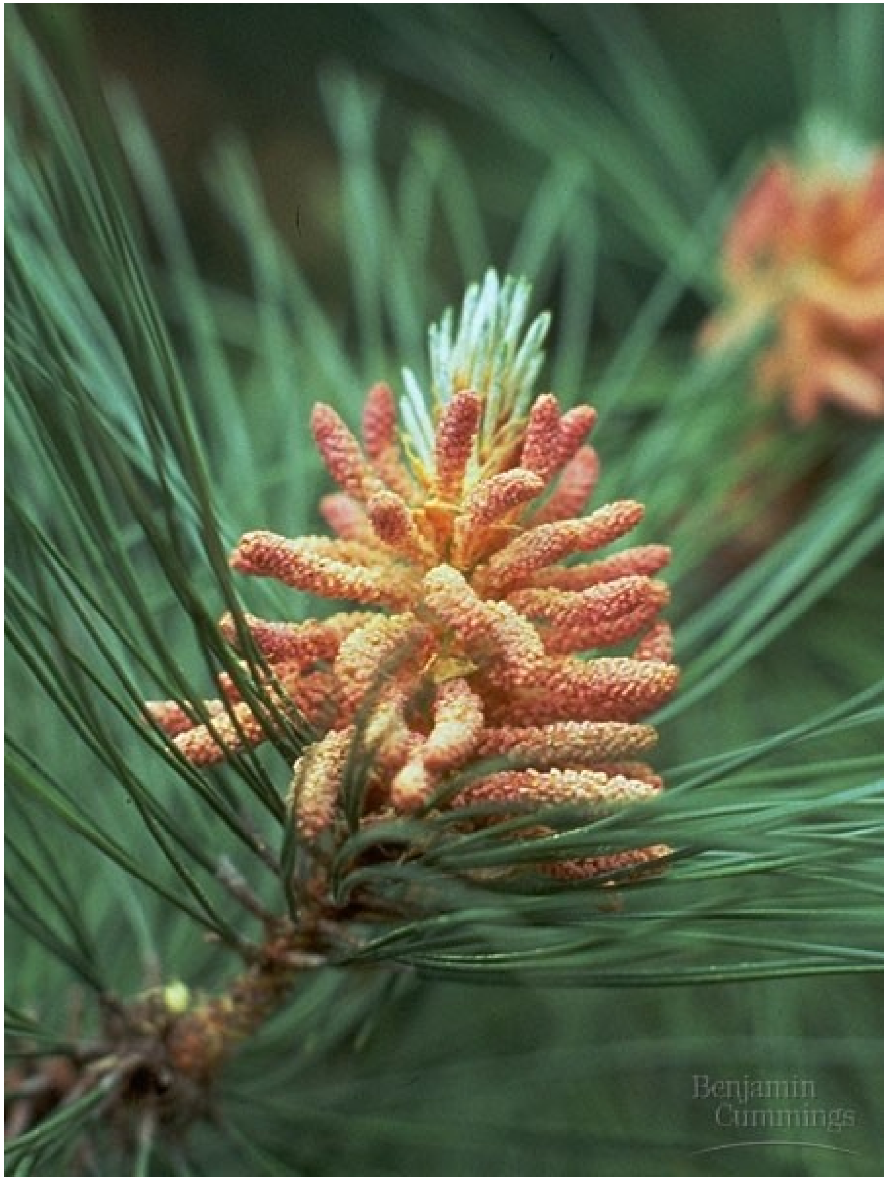


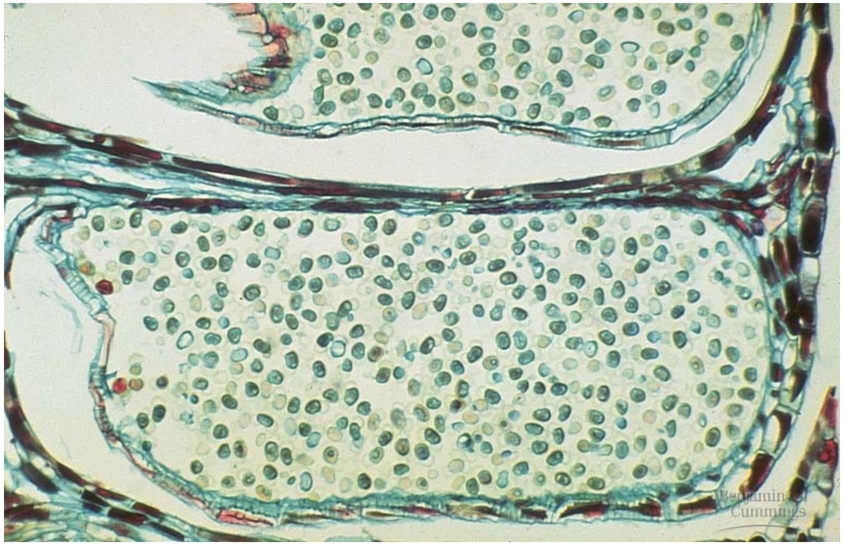
**Phylum Coniferophyta:**
*Sequoiadendron giganteum*, the largest organism there has ever been. (at left)

3200-3300 yrs old
3ft thick bark
20-26ft diameter trunk
300+ ft tall

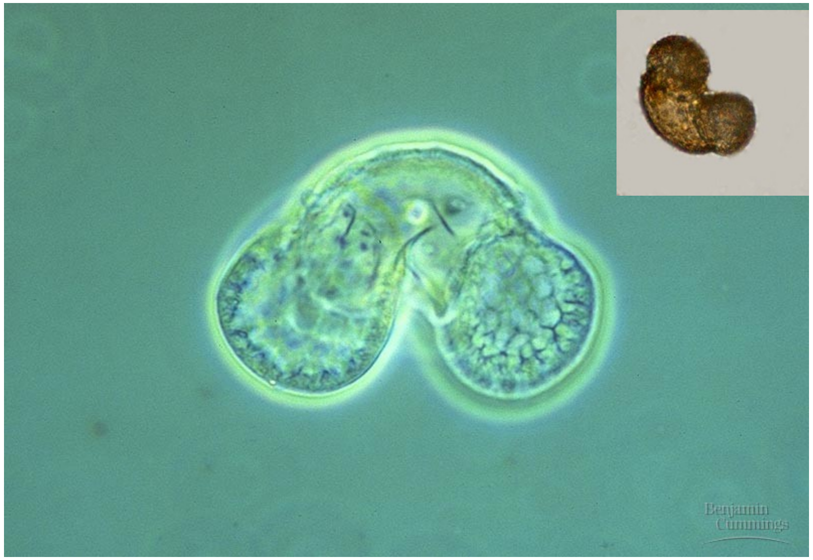
Oldest tree is also a conifer, "Methuselah" bristlecone pine at 4853yrs old (at right). Bristlecone pines live in the White Mountains, CA as well as in Nevada and Utah.

# A closer look at pine cones (*Pinus* sp.)



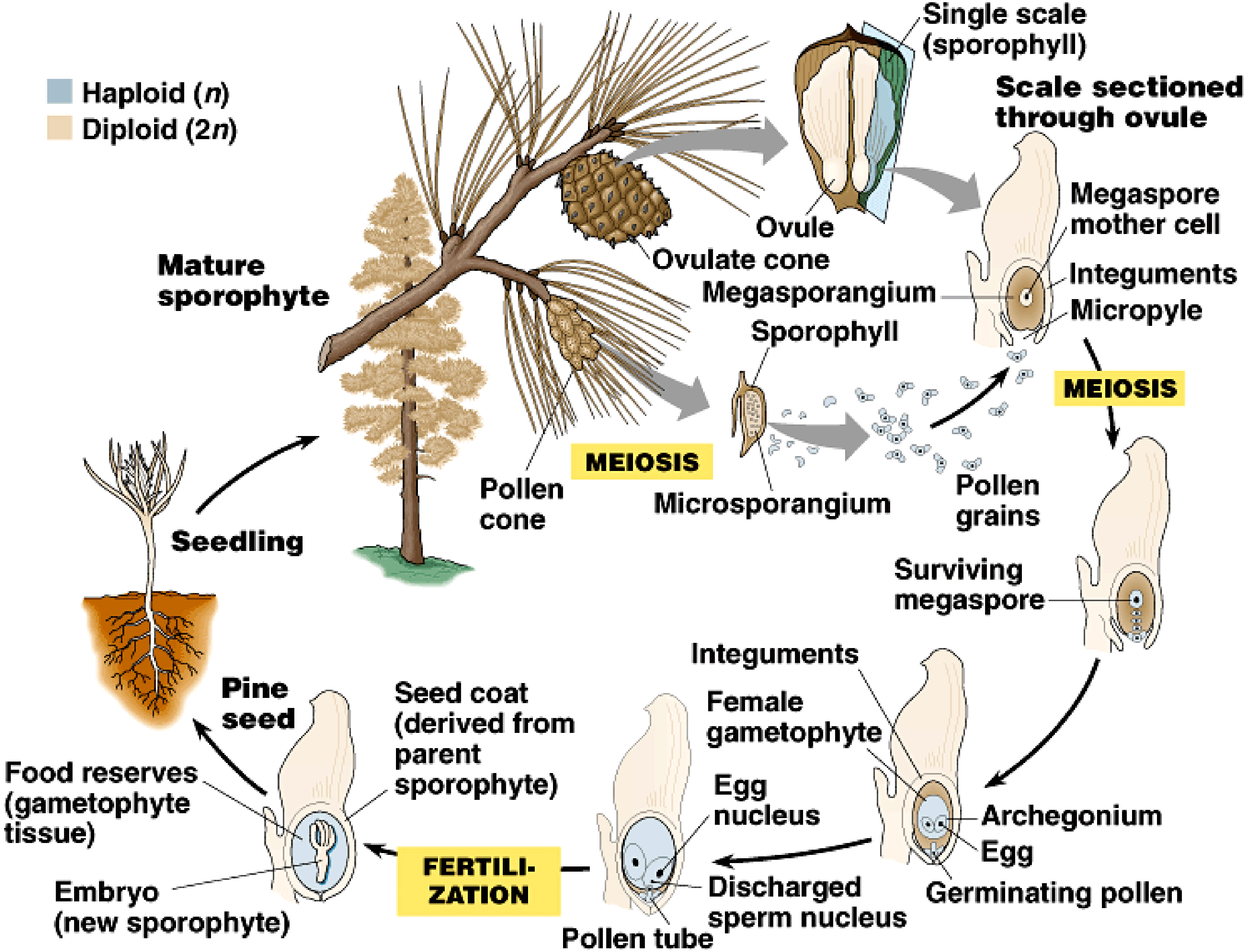


Pine Sporangium with spores



Pine pollen

# The life cycle of a pine - a gymnosperm



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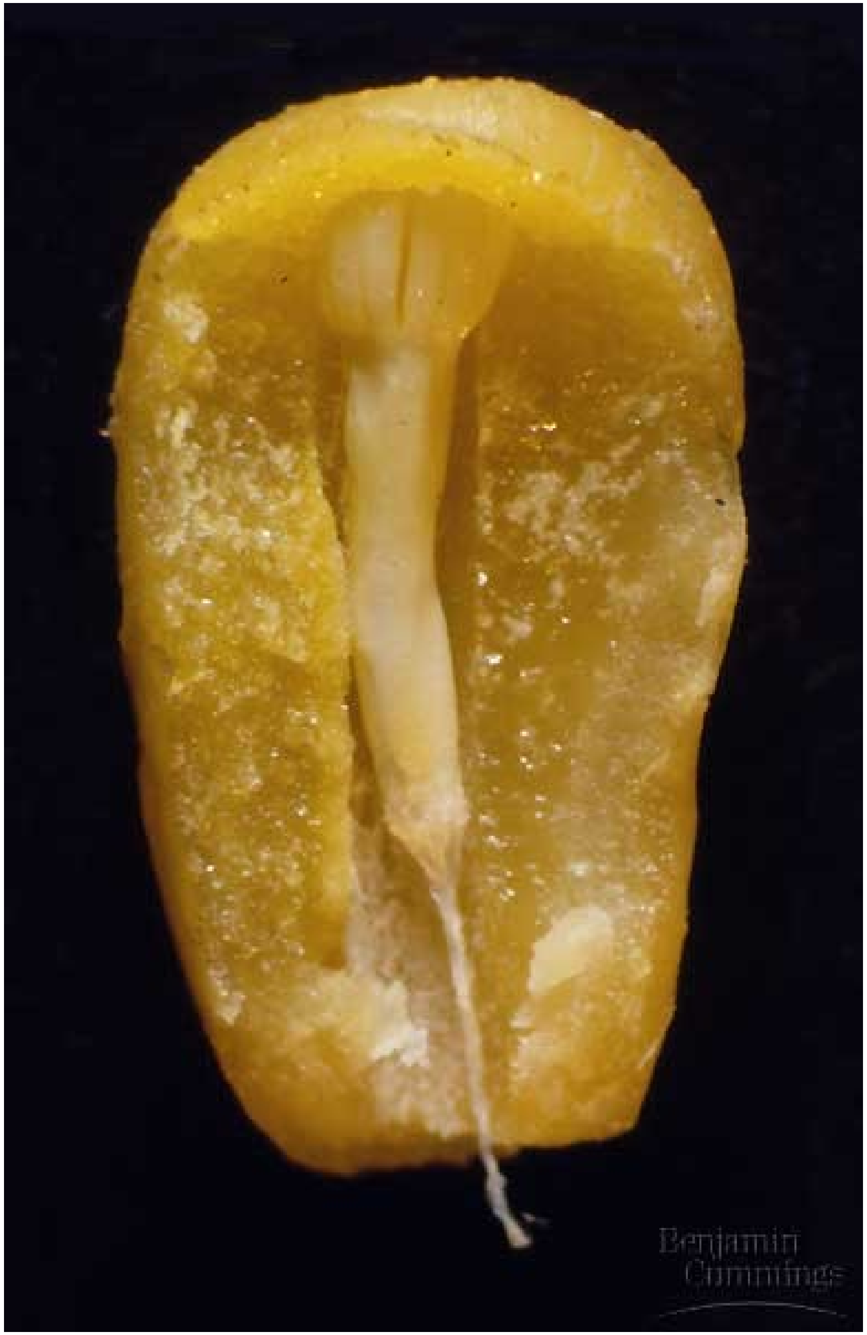
# Pine embryo (pine nut)

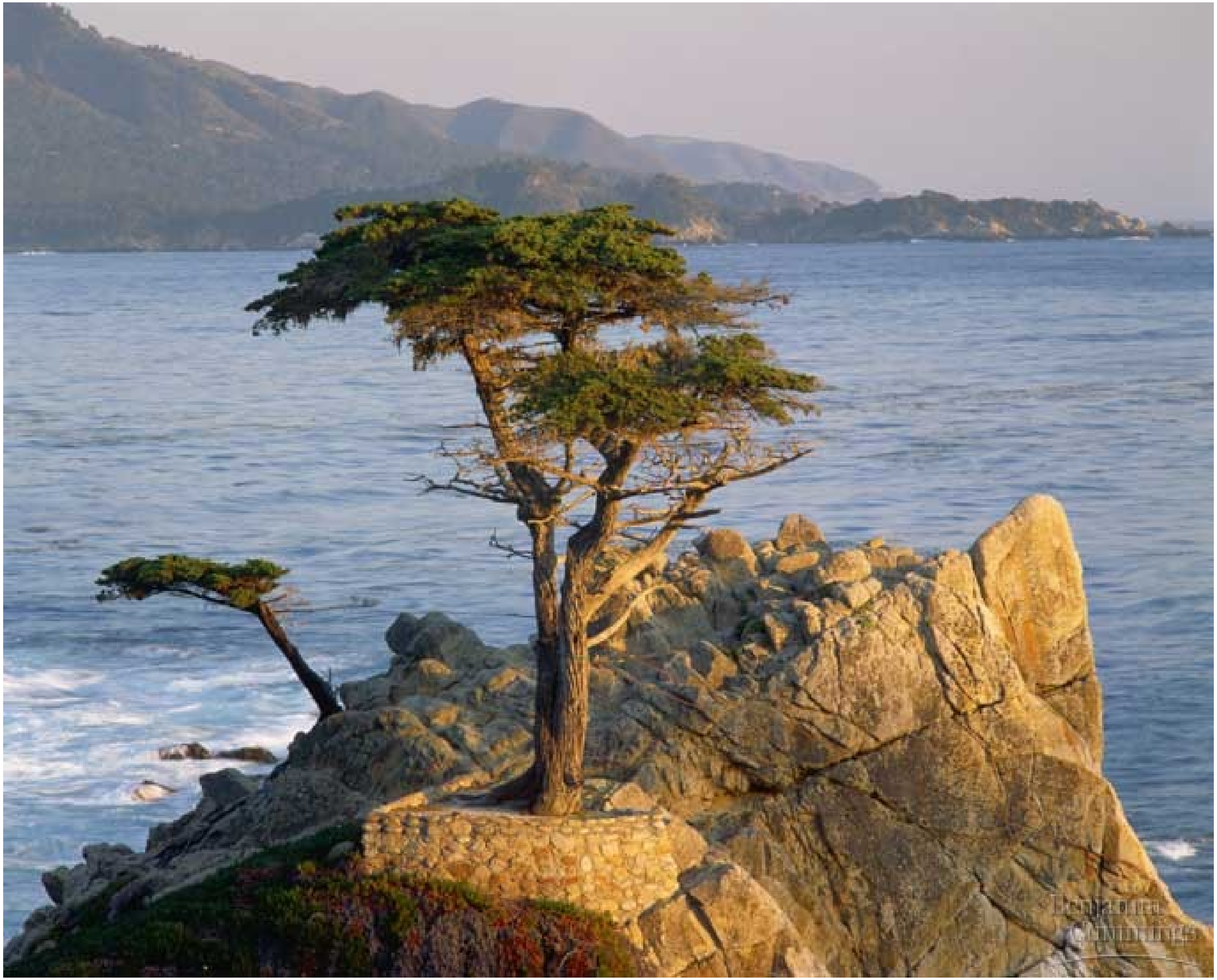


## Nutrition summary:

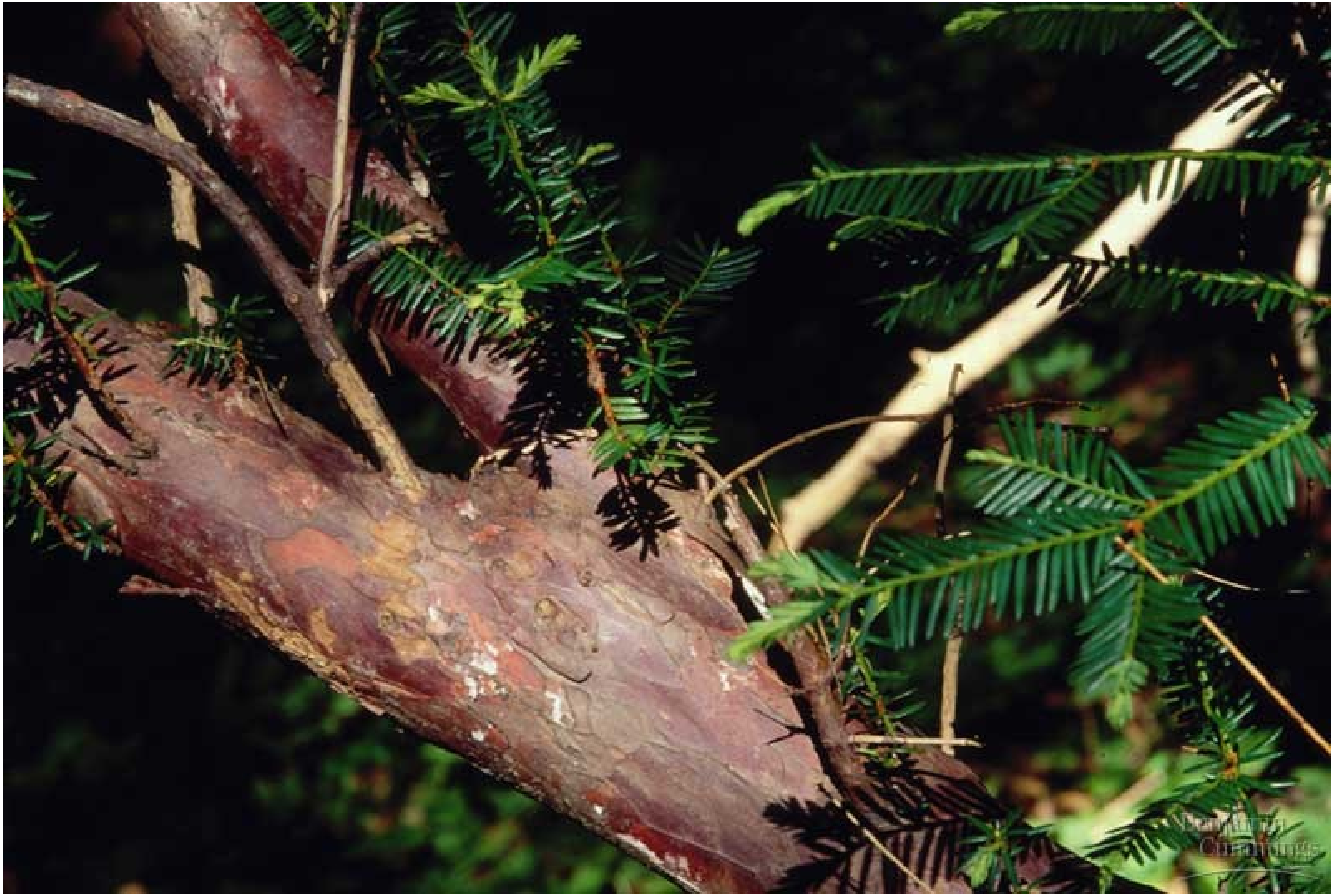
There are **673 calories** in 100 g (~ 4 oz) of Pine Nuts (Pignolias).

Calorie breakdown: **85% fat**, 7% carbs, 8% protein.

# Phylum Coniferophyta: Cypress (the Lone Cypress)

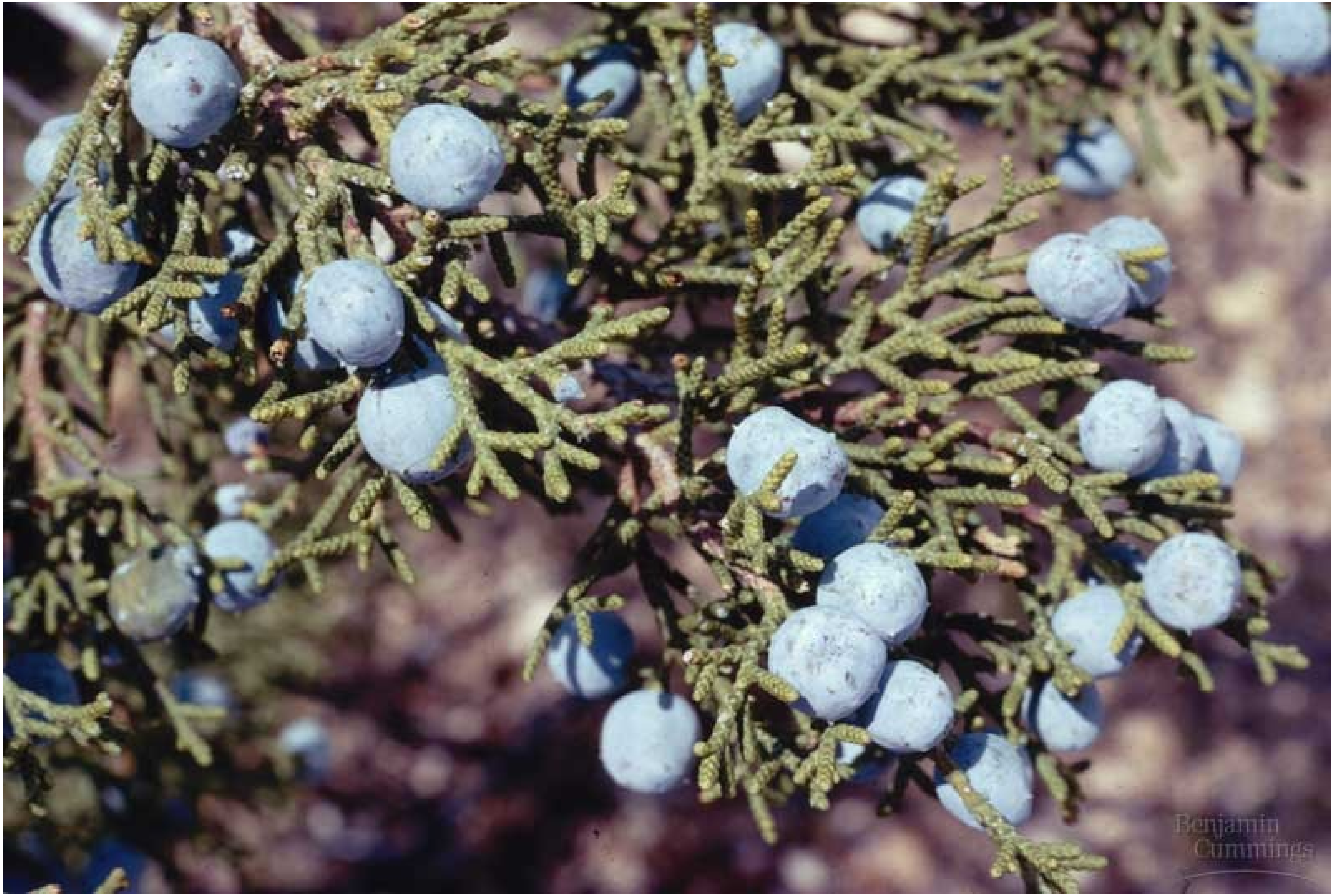


# Phylum Coniferophyta: Pacific yew



Benjamin Cummings

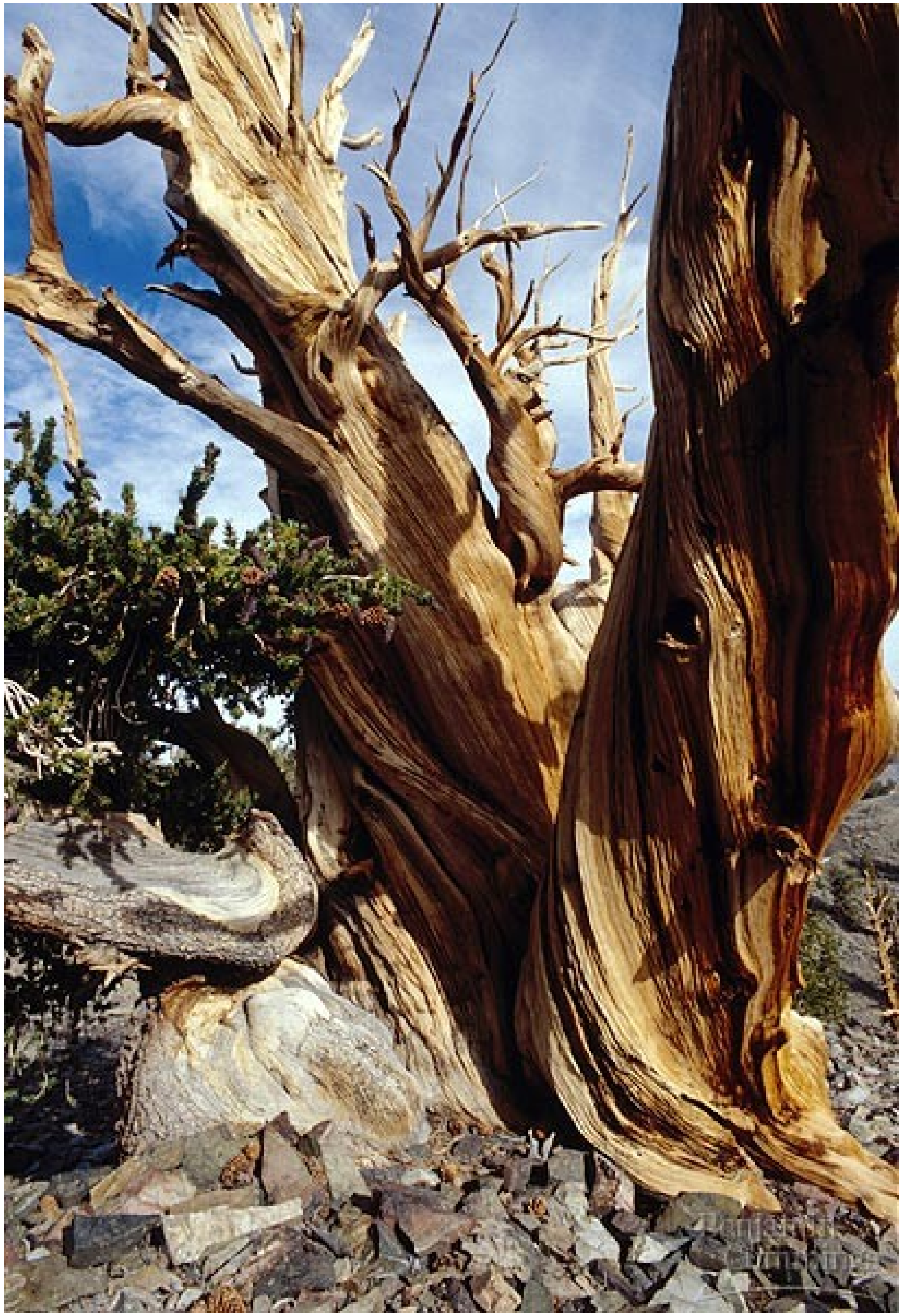
# Phylum Coniferophyta: Common juniper



# Phylum Coniferophyta: A pine farm

Benjamin Cummings

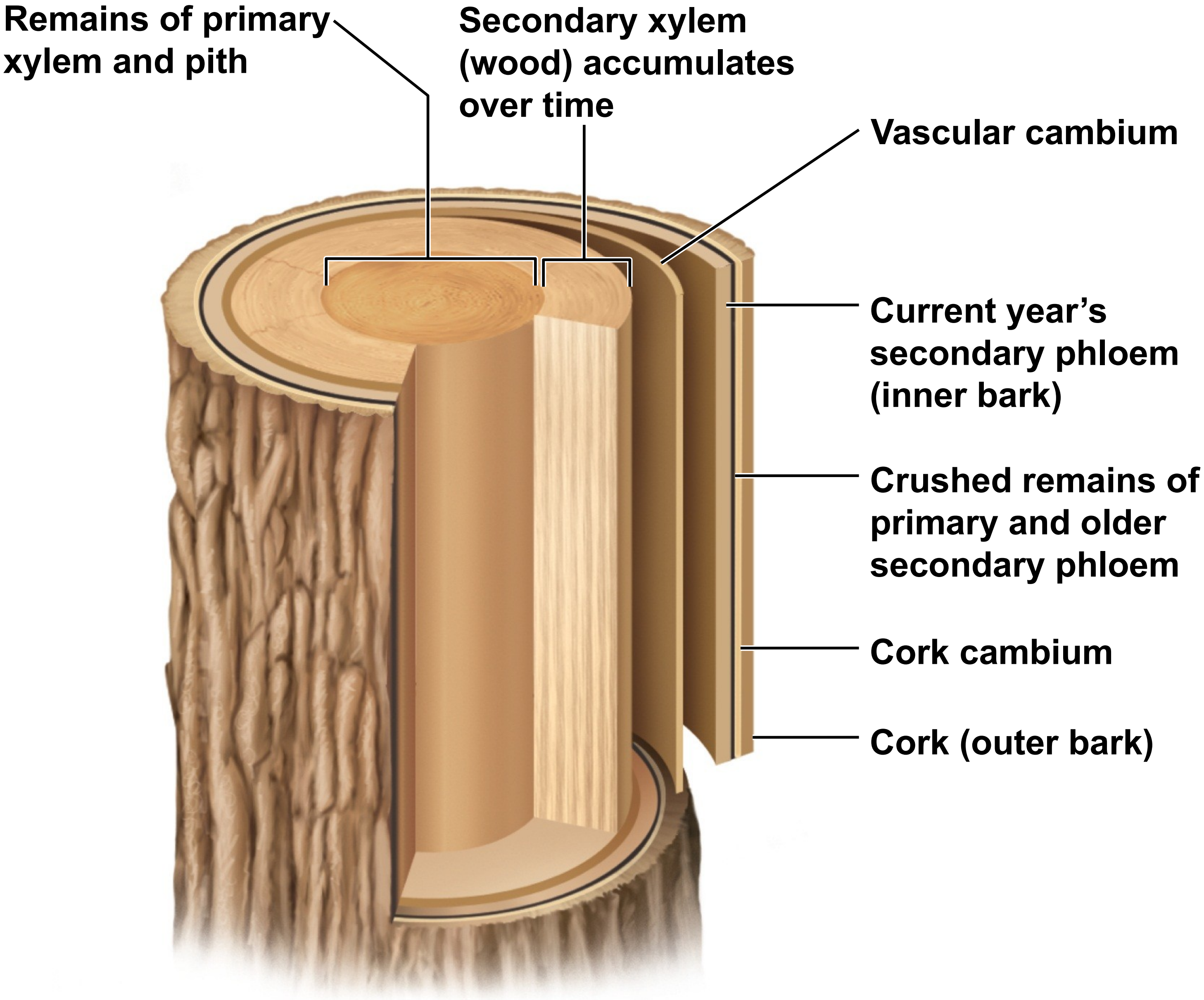
# Bristlecone Pine



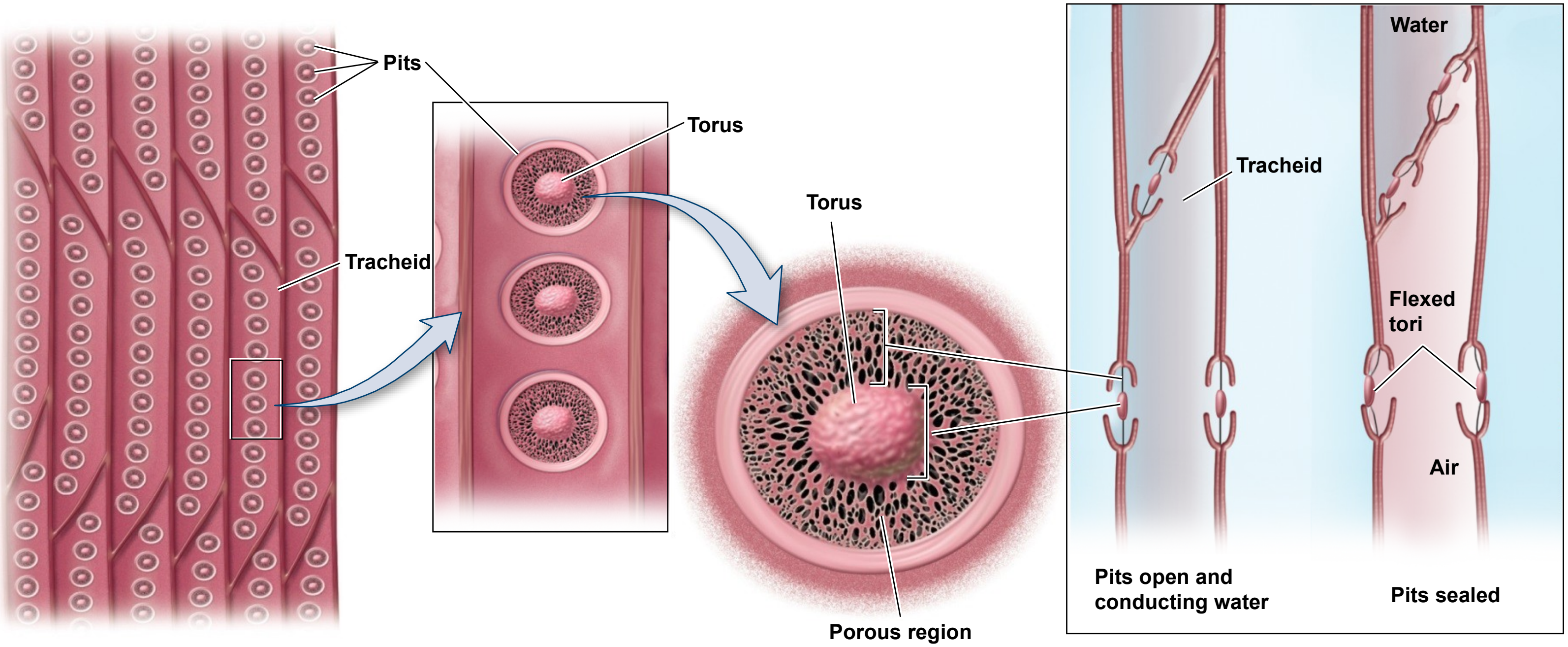
Bristlecone pine on Kaiser Pass, Fresno County.
Numerous specimens across their range have been aged at > 4-5,000 years old

# Wood –WHAT IS IT?

- Tissue composed of numerous empty water-conducting cells strengthened by **lignin (a complex organic polymer)**
  - Allows woody tissue to transport water upward for great distances
  - Also provides structural support
- **Vascular cambium**
  - Produces thick layer of wood and thin layer of inner bark
  - Inner bark (with phloem tubes) used for transporting watery solutions of organic compounds (sugars)


Remains of primary xylem and pith
Secondary xylem (wood) accumulates over time
Vascular cambium
Current year's secondary phloem (inner bark)
Crushed remains of primary and older secondary phloem
Cork cambium
Cork (outer bark)

- Wood contains **tracheids** for water transport (**see later this pptx**)
  - Pits on side and end walls through which water moves
  - Valve-like torus prevents spread of air bubbles (gymnosperms)
- **Resin ducts** – resin helps prevent attack by pathogens and herbivores



(a) Columns of tracheids showing cell walls

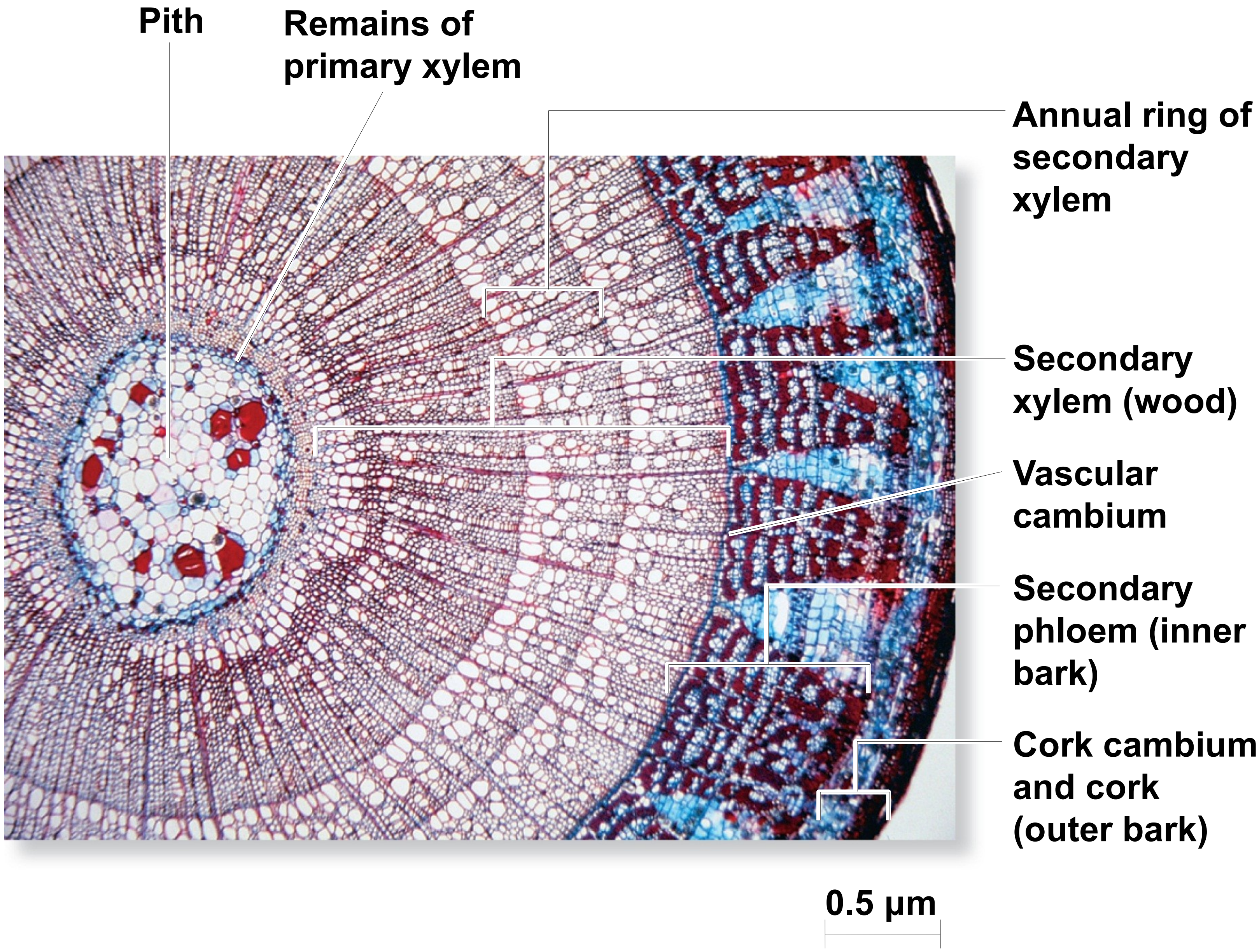
(b) Tracheid pits containing tori

(c) Tracheid with open pits (left side) and tracheid with sealed pits (right side)

# Secondary vascular tissue

- Woody plants begin life as herbaceous seedlings that possess only primary vascular systems
- **Secondary xylem** – wood
- **Secondary phloem** – inner bark
- Bark has both **outer bark** (mostly dead cork cells) and **inner bark** (secondary phloem)
- Secondary vascular tissues produced by two types of secondary meristems (lateral meristems)
  - ❑ **Vascular cambium** – derived from procambium
  - ❑ **Cork cambium** – derived from ground tissue (tissue that is not dermal or vascular) PCS

❑ Meristem = cambium = growing region of active mitosis


Pith
Remains of primary xylem
Annual ring of secondary xylem
Secondary xylem (wood)
Vascular cambium
Secondary phloem (inner bark)
Cork cambium and cork (outer bark)
0.5 μm

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# Tree wood growth